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2nd Edition

Web Scraping with Python

COLLECTING MORE DATA FROM THE MODERN WEB

Ryan Mitchell

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Web Scraping with Python

If programming is magic, then web scraping is surely a form of wizardry. By writing a simple automated program, you can query web servers, request data, and parse it to extract the information you need. The expanded edition of this practical book not only introduces web scraping, but also serves as a comprehensive guide to scraping almost every type of data from the modern web.

Part I focuses on web scraping mechanics: using Python to request information from a web server, performing basic handling of the server's response, and interacting with sites in an automated fashion. Part II explores a variety of more specific tools and applications to fit any web scraping scenario you're likely to encounter.

- Parse complicated HTML pages
- Develop crawlers with the Scrapy framework
- Learn methods to store data you scrape
- Read and extract data from documents
- Clean and normalize badly formatted data
- Read and write natural languages
- Crawl through forms and logins
- Scrape JavaScript and crawl through APIs
- Use and write image-to-text software
- Avoid scraping traps and bot blockers
- Use scrapers to test your website

"The tools and examples included in the book allowed me to easily automate several repetitive tasks, freeing that time to solve more interesting problems. It is a results-oriented, quick read that is well rooted in real-world problems and solutions."

—Eric VanWyk
Electrical Computer Engineer,
Olin College of Engineering

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SECOND EDITION

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Ryan Mitchell

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by Ryan Mitchell

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Preface

To those who have not developed the skill, computer programming can seem like a kind of magic. If programming is magic, *web scraping* is wizardry: the application of magic for particularly impressive and useful—yet surprisingly effortless—feats.

In my years as a software engineer, I've found that few programming practices capture the excitement of both programmers and laymen alike quite like web scraping. The ability to write a simple bot that collects data and streams it down a terminal or stores it in a database, while not difficult, never fails to provide a certain thrill and sense of possibility, no matter how many times you might have done it before.

Unfortunately, when I speak to other programmers about web scraping, there's a lot of misunderstanding and confusion about the practice. Some people aren't sure it's legal (it is), or how to handle problems like JavaScript-heavy pages or required logins. Many are confused about how to start a large web scraping project, or even where to find the data they're looking for. This book seeks to put an end to many of these common questions and misconceptions about web scraping, while providing a comprehensive guide to most common web scraping tasks.

Web scraping is a diverse and fast-changing field, and I've tried to provide both high-level concepts and concrete examples to cover just about any data collection project you're likely to encounter. Throughout the book, code samples are provided to demonstrate these concepts and allow you to try them out. The code samples themselves can be used and modified with or without attribution (although acknowledgment is always appreciated). All code samples are available on GitHub for viewing and downloading.

What Is Web Scraping?

The automated gathering of data from the internet is nearly as old as the internet itself. Although *web scraping* is not a new term, in years past the practice has been more commonly known as *screen scraping*, *data mining*, *web harvesting*, or similar

variations. General consensus today seems to favor *web scraping*, so that is the term I use throughout the book, although I also refer to programs that specifically traverse multiple pages as *web crawlers* or refer to the web scraping programs themselves as *bots*.

In theory, web scraping is the practice of gathering data through any means other than a program interacting with an API (or, obviously, through a human using a web browser). This is most commonly accomplished by writing an automated program that queries a web server, requests data (usually in the form of HTML and other files that compose web pages), and then parses that data to extract needed information.

In practice, web scraping encompasses a wide variety of programming techniques and technologies, such as data analysis, natural language parsing, and information security. Because the scope of the field is so broad, this book covers the fundamental basics of web scraping and crawling in Part I and delves into advanced topics in Part II. I suggest that all readers carefully study the first part and delve into the more specific in the second part as needed.

Why Web Scraping?

If the only way you access the internet is through a browser, you're missing out on a huge range of possibilities. Although browsers are handy for executing JavaScript, displaying images, and arranging objects in a more human-readable format (among other things), web scrapers are excellent at gathering and processing large amounts of data quickly. Rather than viewing one page at a time through the narrow window of a monitor, you can view databases spanning thousands or even millions of pages at once.

In addition, web scrapers can go places that traditional search engines cannot. A Google search for "cheapest flights to Boston" will result in a slew of advertisements and popular flight search sites. Google knows only what these websites say on their content pages, not the exact results of various queries entered into a flight search application. However, a well-developed web scraper can chart the cost of a flight to Boston over time, across a variety of websites, and tell you the best time to buy your ticket.

You might be asking: "Isn't data gathering what APIs are for?" (If you're unfamiliar with APIs, see Chapter 12.) Well, APIs can be fantastic, if you find one that suits your purposes. They are designed to provide a convenient stream of well-formatted data from one computer program to another. You can find an API for many types of data you might want to use, such as Twitter posts or Wikipedia pages. In general, it is preferable to use an API (if one exists), rather than build a bot to get the same data. However, an API might not exist or be useful for your purposes, for several reasons:

- You are gathering relatively small, finite sets of data across a large collection of websites without a cohesive API.
- The data you want is fairly small or uncommon, and the creator did not think it warranted an API.
- The source does not have the infrastructure or technical ability to create an API.
- The data is valuable and/or protected and not intended to be spread widely.

Even when an API *does* exist, the request volume and rate limits, the types of data, or the format of data that it provides might be insufficient for your purposes.

This is where web scraping steps in. With few exceptions, if you can view data in your browser, you can access it via a Python script. If you can access it in a script, you can store it in a database. And if you can store it in a database, you can do virtually anything with that data.

There are obviously many extremely practical applications of having access to nearly unlimited data: market forecasting, machine-language translation, and even medical diagnostics have benefited tremendously from the ability to retrieve and analyze data from news sites, translated texts, and health forums, respectively.

Even in the art world, web scraping has opened up new frontiers for creation. The 2006 project "We Feel Fine" by Jonathan Harris and Sep Kamvar scraped a variety of English-language blog sites for phrases starting with "I feel" or "I am feeling." This led to a popular data visualization, describing how the world was feeling day by day and minute by minute.

Regardless of your field, web scraping almost always provides a way to guide business practices more effectively, improve productivity, or even branch off into a brand-new field entirely.

About This Book

This book is designed to serve not only as an introduction to web scraping, but as a comprehensive guide to collecting, transforming, and using data from uncooperative sources. Although it uses the Python programming language and covers many Python basics, it should not be used as an introduction to the language.

If you don't know any Python at all, this book might be a bit of a challenge. Please do not use it as an introductory Python text. With that said, I've tried to keep all concepts and code samples at a beginning-to-intermediate Python programming level in order to make the content accessible to a wide range of readers. To this end, there are occasional explanations of more advanced Python programming and general computer science topics where appropriate. If you are a more advanced reader, feel free to skim these parts!

If you're looking for a more comprehensive Python resource, *Introducing Python* by Bill Lubanovic (O'Reilly) is a good, if lengthy, guide. For those with shorter attention spans, the video series *Introduction to Python* by Jessica McKellar (O'Reilly) is an excellent resource. I've also enjoyed *Think Python* by a former professor of mine, Allen Downey (O'Reilly). This last book in particular is ideal for those new to programming, and teaches computer science and software engineering concepts along with the Python language.

Technical books are often able to focus on a single language or technology, but web scraping is a relatively disparate subject, with practices that require the use of databases, web servers, HTTP, HTML, internet security, image processing, data science, and other tools. This book attempts to cover all of these, and other topics, from the perspective of "data gathering." It should not be used as a complete treatment of any of these subjects, but I believe they are covered in enough detail to get you started writing web scrapers!

Part I covers the subject of web scraping and web crawling in depth, with a strong focus on a small handful of libraries used throughout the book. Part I can easily be used as a comprehensive reference for these libraries and techniques (with certain exceptions, where additional references will be provided). The skills taught in the first part will likely be useful for everyone writing a web scraper, regardless of their particular target or application.

Part II covers additional subjects that the reader might find useful when writing web scrapers, but that might not be useful for all scrapers all the time. These subjects are, unfortunately, too broad to be neatly wrapped up in a single chapter. Because of this, frequent references are made to other resources for additional information.

The structure of this book enables you to easily jump around among chapters to find only the web scraping technique or information that you are looking for. When a concept or piece of code builds on another mentioned in a previous chapter, I explicitly reference the section that it was addressed in.

Conventions Used in This Book

The following typographical conventions are used in this book:

Italic
: Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`
: Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

`Constant width bold`
: Shows commands or other text that should be typed by the user.

`Constant width italic`
: Shows text that should be replaced with user-supplied values or by values determined by context.

This element signifies a tip or suggestion.

This element signifies a general note.

This element indicates a warning or caution.

Using Code Examples

Supplemental material (code examples, exercises, etc.) is available for download at *https://github.com/REMitchell/python-scraping*.

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Unfortunately, printed books are difficult to keep up-to-date. With web scraping, this provides an additional challenge, as the many libraries and websites that the book references and that the code often depends on may occasionally be modified, and code samples may fail or produce unexpected results. If you choose to run the code samples, please run them from the GitHub repository rather than copying from the book directly. I, and readers of this book who choose to contribute (including, perhaps, you!), will strive to keep the repository up-to-date with required modifications and notes.

In addition to code samples, terminal commands are often provided to illustrate how to install and run software. In general, these commands are geared toward Linux-based operating systems, but will usually be applicable for Windows users with a properly configured Python environment and pip installation. When this is not the case, I have provided instructions for all major operating systems, or external references for Windows users to accomplish the task.

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Finally, thanks to Jim Waldo, who really started this whole thing many years ago when he mailed a Linux box and *The Art and Science of C* to a young and impressionable teenager.

PART I

Building Scrapers

This first part of this book focuses on the basic mechanics of web scraping: how to use Python to request information from a web server, how to perform basic handling of the server's response, and how to begin interacting with a website in an automated fashion. By the end, you'll be cruising around the internet with ease, building scrapers that can hop from one domain to another, gather information, and store that information for later use.

To be honest, web scraping is a fantastic field to get into if you want a huge payout for relatively little upfront investment. In all likelihood, 90% of web scraping projects you'll encounter will draw on techniques used in just the next six chapters. This section covers what the general (albeit technically savvy) public tends to think of when they think of "web scrapers":

- Retrieving HTML data from a domain name
- Parsing that data for target information
- Storing the target information
- Optionally, moving to another page to repeat the process

This will give you a solid foundation before moving on to more complex projects in Part II. Don't be fooled into thinking that this first section isn't as important as some of the more advanced projects in the second half. You will use nearly all the information in the first half of this book on a daily basis while writing web scrapers!

CHAPTER 1

Your First Web Scraper

Once you start web scraping, you start to appreciate all the little things that browsers do for you. The web, without a layer of HTML formatting, CSS styling, JavaScript execution, and image rendering, can look a little intimidating at first, but in this chapter, as well as the next one, we'll cover how to format and interpret data without the help of a browser.

This chapter starts with the basics of sending a `GET` request (a request to fetch, or "get," the content of a web page) to a web server for a specific page, reading the HTML output from that page, and doing some simple data extraction in order to isolate the content that you are looking for.

Connecting

If you haven't spent much time in networking or network security, the mechanics of the internet might seem a little mysterious. You don't want to think about what, exactly, the network is doing every time you open a browser and go to *http://google.com*, and, these days, you don't have to. In fact, I would argue that it's fantastic that computer interfaces have advanced to the point where most people who use the internet don't have the faintest idea about how it works.

However, web scraping requires stripping away some of this shroud of interface—not just at the browser level (how it interprets all of this HTML, CSS, and JavaScript), but occasionally at the level of the network connection.

To give you an idea of the infrastructure required to get information to your browser, let's use the following example. Alice owns a web server. Bob uses a desktop computer, which is trying to connect to Alice's server. When one machine wants to talk to another machine, something like the following exchange takes place:

1. Bob's computer sends along a stream of 1 and 0 bits, indicated by high and low voltages on a wire. These bits form some information, containing a header and body. The header contains an immediate destination of his local router's MAC address, with a final destination of Alice's IP address. The body contains his request for Alice's server application.
2. Bob's local router receives all these 1s and 0s and interprets them as a packet, from Bob's own MAC address, destined for Alice's IP address. His router stamps its own IP address on the packet as the "from" IP address, and sends it off across the internet.
3. Bob's packet traverses several intermediary servers, which direct his packet toward the correct physical/wired path, on to Alice's server.
4. Alice's server receives the packet at her IP address.
5. Alice's server reads the packet port destination in the header, and passes it off to the appropriate application—the web server application. (The packet port destination is almost always port 80 for web applications; this can be thought of as an apartment number for packet data, whereas the IP address is like the street address.)
6. The web server application receives a stream of data from the server processor. This data says something like the following:

   - This is a `GET` request.

   - The following file is requested: *index.html*.
7. The web server locates the correct HTML file, bundles it up into a new packet to send to Bob, and sends it through to its local router, for transport back to Bob's machine, through the same process.

And voilà! We have The Internet.

So, where in this exchange did the web browser come into play? Absolutely nowhere. In fact, browsers are a relatively recent invention in the history of the internet, considering Nexus was released in 1990.

Yes, the web browser is a useful application for creating these packets of information, telling your operating system to send them off, and interpreting the data you get back as pretty pictures, sounds, videos, and text. However, a web browser is just code, and code can be taken apart, broken into its basic components, rewritten, reused, and made to do anything you want. A web browser can tell the processor to send data to the application that handles your wireless (or wired) interface, but you can do the same thing in Python with just three lines of code:

```
from urllib.request import urlopen

html = urlopen('http://pythonscraping.com/pages/page1.html')
print(html.read())
```

To run this, you can use the iPython notebook for Chapter 1 in the GitHub repository, or you can save it locally as *scrapetest.py* and run it in your terminal by using this command:

```
$ python scrapetest.py
```

Note that if you also have Python 2.x installed on your machine and are running both versions of Python side by side, you may need to explicitly call Python 3.x by running the command this way:

```
$ python3 scrapetest.py
```

This command outputs the complete HTML code for *page1* located at the URL *http://pythonscraping.com/pages/page1.html*. More accurately, this outputs the HTML file *page1.html*, found in the directory *<web root>/pages*, on the server located at the domain name *http://pythonscraping.com*.

Why is it important to start thinking of these addresses as "files" rather than "pages"? Most modern web pages have many resource files associated with them. These could be image files, JavaScript files, CSS files, or any other content that the page you are requesting is linked to. When a web browser hits a tag such as `<img src="cuteKitten.jpg">`, the browser knows that it needs to make another request to the server to get the data at the file *cuteKitten.jpg* in order to fully render the page for the user.

Of course, your Python script doesn't have the logic to go back and request multiple files (yet); it can only read the single HTML file that you've directly requested.

```
from urllib.request import urlopen
```

means what it looks like it means: it looks at the Python module request (found within the *urllib* library) and imports only the function `urlopen`.

urllib is a standard Python library (meaning you don't have to install anything extra to run this example) and contains functions for requesting data across the web, handling cookies, and even changing metadata such as headers and your user agent. We will be using *urllib* extensively throughout the book, so I recommend you read the Python documentation for the library.

`urlopen` is used to open a remote object across a network and read it. Because it is a fairly generic function (it can read HTML files, image files, or any other file stream with ease), we will be using it quite frequently throughout the book.

An Introduction to BeautifulSoup

> Beautiful Soup, so rich and green,
> Waiting in a hot tureen!
> Who for such dainties would not stoop?
> Soup of the evening, beautiful Soup!

The *BeautifulSoup* library was named after a Lewis Carroll poem of the same name in *Alice's Adventures in Wonderland*. In the story, this poem is sung by a character called the Mock Turtle (itself a pun on the popular Victorian dish Mock Turtle Soup made not of turtle but of cow).

Like its Wonderland namesake, *BeautifulSoup* tries to make sense of the nonsensical; it helps format and organize the messy web by fixing bad HTML and presenting us with easily traversable Python objects representing XML structures.

Installing BeautifulSoup

Because the *BeautifulSoup* library is not a default Python library, it must be installed. If you're already experienced at installing Python libraries, please use your favorite installer and skip ahead to the next section, "Running BeautifulSoup" on page 8.

For those who have not installed Python libraries (or need a refresher), this general method will be used for installing multiple libraries throughout the book, so you may want to reference this section in the future.

We will be using the BeautifulSoup 4 library (also known as BS4) throughout this book. The complete instructions for installing BeautifulSoup 4 can be found at Crummy.com; however, the basic method for Linux is shown here:

```
$ sudo apt-get install python-bs4
```

And for Macs:

```
$ sudo easy_install pip
```

This installs the Python package manager *pip*. Then run the following to install the library:

```
$ pip install beautifulsoup4
```

Again, note that if you have both Python 2.x and 3.x installed on your machine, you might need to call `python3` explicitly:

```
$ python3 myScript.py
```

Make sure to also use this when installing packages, or the packages might be installed under Python 2.x, but not Python 3.x:

```
$ sudo python3 setup.py install
```

If using pip, you can also call `pip3` to install the Python 3.x versions of packages:

```
$ pip3 install beautifulsoup4
```

Installing packages in Windows is nearly identical to the process for Mac and Linux. Download the most recent BeautifulSoup 4 release from the download page, navigate to the directory you unzipped it to, and run this:

```
> python setup.py install
```

And that's it! BeautifulSoup will now be recognized as a Python library on your machine. You can test this out by opening a Python terminal and importing it:

```
$ python
> from bs4 import BeautifulSoup
```

The import should complete without errors.

In addition, there is an *.exe* installer for pip on Windows, so you can easily install and manage packages:

```
> pip install beautifulsoup4
```

Keeping Libraries Straight with Virtual Environments

If you intend to work on multiple Python projects, or you need a way to easily bundle projects with all associated libraries, or you're worried about potential conflicts between installed libraries, you can install a Python virtual environment to keep everything separated and easy to manage.

When you install a Python library without a virtual environment, you are installing it *globally*. This usually requires that you be an administrator, or run as root, and that the Python library exists for every user and every project on the machine. Fortunately, creating a virtual environment is easy:

```
$ virtualenv scrapingEnv
```

This creates a new environment called *scrapingEnv*, which you must activate to use:

```
$ cd scrapingEnv/
$ source bin/activate
```

After you have activated the environment, you will see that environment's name in your command-line prompt, reminding you that you're currently working with it. Any libraries you install or scripts you run will be under that virtual environment only.

Working in the newly created `scrapingEnv` environment, you can install and use BeautifulSoup; for instance:

```
(scrapingEnv)ryan$ pip install beautifulsoup4
(scrapingEnv)ryan$ python
> from bs4 import BeautifulSoup
>
```

You can leave the environment with the `deactivate` command, after which you can no longer access any libraries that were installed inside the virtual environment:

```
(scrapingEnv)ryan$ deactivate
ryan$ python
> from bs4 import BeautifulSoup
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ImportError: No module named 'bs4'
```

Keeping all your libraries separated by project also makes it easy to zip up the entire environment folder and send it to someone else. As long as they have the same version of Python installed on their machine, your code will work from the virtual environment without requiring them to install any libraries themselves.

Although I won't explicitly instruct you to use a virtual environment in all of this book's examples, keep in mind that you can apply a virtual environment anytime simply by activating it beforehand.

Running BeautifulSoup

The most commonly used object in the BeautifulSoup library is, appropriately, the `BeautifulSoup` object. Let's take a look at it in action, modifying the example found in the beginning of this chapter:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup

html = urlopen('http://www.pythonscraping.com/pages/page1.html')
bs = BeautifulSoup(html.read(), 'html.parser')
print(bs.h1)
```

The output is as follows:

```
<h1>An Interesting Title</h1>
```

Note that this returns only the first instance of the `h1` tag found on the page. By convention, only one `h1` tag should be used on a single page, but conventions are often broken on the web, so you should be aware that this will retrieve the first instance of the tag only, and not necessarily the one that you're looking for.

As in previous web scraping examples, you are importing the `urlopen` function and calling `html.read()` in order to get the HTML content of the page. In addition to the text string, BeautifulSoup can also use the file object directly returned by `urlopen`, without needing to call `.read()` first:

```
bs = BeautifulSoup(html, 'html.parser')
```

This HTML content is then transformed into a `BeautifulSoup` object, with the following structure:

- **html** → *<html><head>...</head><body>...</body></html>*
  - **head** → *<head><title>A Useful Page<title></head>*
    - **title** → *<title>A Useful Page</title>*
  - **body** → *<body><h1>An Int...</h1><div>Lorem ip...</div></body>*
    - **h1** → *<h1>An Interesting Title</h1>*
    - **div** → *<div>Lorem Ipsum dolor...</div>*

Note that the `h1` tag that you extract from the page is nested two layers deep into your `BeautifulSoup` object structure (`html` → `body` → `h1`). However, when you actually fetch it from the object, you call the `h1` tag directly:

```
bs.h1
```

In fact, any of the following function calls would produce the same output:

```
bs.html.body.h1
bs.body.h1
bs.html.h1
```

When you create a `BeautifulSoup` object, two arguments are passed in:

```
bs = BeautifulSoup(html.read(), 'html.parser')
```

The first is the HTML text the object is based on, and the second specifies the parser that you want BeautifulSoup to use in order to create that object. In the majority of cases, it makes no difference which parser you choose.

`html.parser` is a parser that is included with Python 3 and requires no extra installations in order to use. Except where required, we will use this parser throughout the book.

Another popular parser is lxml. This can be installed through pip:

```
$ pip3 install lxml
```

lxml can be used with BeautifulSoup by changing the parser string provided:

```
bs = BeautifulSoup(html.read(), 'lxml')
```

lxml has some advantages over html.parser in that it is generally better at parsing "messy" or malformed HTML code. It is forgiving and fixes problems like unclosed tags, tags that are improperly nested, and missing head or body tags. It is also somewhat faster than `html.parser`, although speed is not necessarily an advantage in web scraping, given that the speed of the network itself will almost always be your largest bottleneck.

One of the disadvantages of lxml is that it has to be installed separately and depends on third-party C libraries to function. This can cause problems for portability and ease of use, compared to html.parser.

Another popular HTML parser is `html5lib`. Like lxml, `html5lib` is an extremely forgiving parser that takes even more initiative correcting broken HTML. It also depends on an external dependency, and is slower than both lxml and html.parser. Despite this, it may be a good choice if you are working with messy or handwritten HTML sites.

It can be used by installing and passing the string `html5lib` to the BeautifulSoup object:

```
bs = BeautifulSoup(html.read(), 'html5lib')
```

I hope this small taste of *BeautifulSoup* has given you an idea of the power and simplicity of this library. Virtually any information can be extracted from any HTML (or XML) file, as long as it has an identifying tag surrounding it or near it. Chapter 2 delves more deeply into more-complex BeautifulSoup function calls, and presents regular expressions and how they can be used with `BeautifulSoup` in order to extract information from websites.

Connecting Reliably and Handling Exceptions

The web is messy. Data is poorly formatted, websites go down, and closing tags go missing. One of the most frustrating experiences in web scraping is to go to sleep with a scraper running, dreaming of all the data you'll have in your database the next day—only to find that the scraper hit an error on some unexpected data format and stopped execution shortly after you stopped looking at the screen. In situations like these, you might be tempted to curse the name of the developer who created the website (and the oddly formatted data), but the person you should really be kicking is yourself, for not anticipating the exception in the first place!

Let's take a look at the first line of our scraper, after the import statements, and figure out how to handle any exceptions this might throw:

```
html = urlopen('http://www.pythonscraping.com/pages/page1.html')
```

Two main things can go wrong in this line:

- The page is not found on the server (or there was an error in retrieving it).
- The server is not found.

In the first situation, an HTTP error will be returned. This HTTP error may be "404 Page Not Found," "500 Internal Server Error," and so forth. In all of these cases, the `urlopen` function will throw the generic exception `HTTPError`. You can handle this exception in the following way:

```
from urllib.request import urlopen
from urllib.error import HTTPError

try:
```

```
    html = urlopen('http://www.pythonscraping.com/pages/page1.html')
except HTTPError as e:
    print(e)
    # return null, break, or do some other "Plan B"
else:
    # program continues. Note: If you return or break in the
    # exception catch, you do not need to use the "else" statement
```

If an HTTP error code is returned, the program now prints the error, and does not execute the rest of the program under the `else` statement.

If the server is not found at all (if, say, *http://www.pythonscraping.com* is down, or the URL is mistyped), `urlopen` will throw an `URLError`. This indicates that no server could be reached at all, and, because the remote server is responsible for returning HTTP status codes, an `HTTPError` cannot be thrown, and the more serious `URLError` must be caught. You can add a check to see whether this is the case:

```
from urllib.request import urlopen
from urllib.error import HTTPError
from urllib.error import URLError

try:
    html = urlopen('https://pythonscrapingthisurldoesnotexist.com')
except HTTPError as e:
    print(e)
except URLError as e:
    print('The server could not be found!')
else:
    print('It Worked!')
```

Of course, if the page is retrieved successfully from the server, there is still the issue of the content on the page not quite being what you expected. Every time you access a tag in a `BeautifulSoup` object, it's smart to add a check to make sure the tag actually exists. If you attempt to access a tag that does not exist, BeautifulSoup will return a `None` object. The problem is, attempting to access a tag on a `None` object itself will result in an `AttributeError` being thrown.

The following line (where `nonExistentTag` is a made-up tag, not the name of a real BeautifulSoup function)

```
print(bs.nonExistentTag)
```

returns a `None` object. This object is perfectly reasonable to handle and check for. The trouble comes if you don't check for it, but instead go on and try to call another function on the `None` object, as illustrated in the following:

```
print(bs.nonExistentTag.someTag)
```

This returns an exception:

```
AttributeError: 'NoneType' object has no attribute 'someTag'
```

So how can you guard against these two situations? The easiest way is to explicitly check for both situations:

```
try:
    badContent = bs.nonExistingTag.anotherTag
except AttributeError as e:
    print('Tag was not found')
else:
    if badContent == None:
        print ('Tag was not found')
    else:
        print(badContent)
```

This checking and handling of every error does seem laborious at first, but it's easy to add a little reorganization to this code to make it less difficult to write (and, more important, much less difficult to read). This code, for example, is our same scraper written in a slightly different way:

```
from urllib.request import urlopen
from urllib.error import HTTPError
from bs4 import BeautifulSoup

def getTitle(url):
    try:
        html = urlopen(url)
    except HTTPError as e:
        return None
    try:
        bs = BeautifulSoup(html.read(), 'html.parser')
        title = bs.body.h1
    except AttributeError as e:
        return None
    return title

title = getTitle('http://www.pythonscraping.com/pages/page1.html')
if title == None:
    print('Title could not be found')
else:
    print(title)
```

In this example, you're creating a function `getTitle`, which returns either the title of the page, or a `None` object if there was a problem retrieving it. Inside `getTitle`, you check for an `HTTPError`, as in the previous example, and encapsulate two of the BeautifulSoup lines inside one `try` statement. An `AttributeError` might be thrown from either of these lines (if the server did not exist, `html` would be a `None` object, and `html.read()` would throw an `AttributeError`). You could, in fact, encompass as many lines as you want inside one `try` statement, or call another function entirely, which can throw an `AttributeError` at any point.

When writing scrapers, it's important to think about the overall pattern of your code in order to handle exceptions and make it readable at the same time. You'll also likely want to heavily reuse code. Having generic functions such as `getSiteHTML` and `getTitle` (complete with thorough exception handling) makes it easy to quickly—and reliably—scrape the web.

CHAPTER 2

Advanced HTML Parsing

When Michelangelo was asked how he could sculpt a work of art as masterful as his *David*, he is famously reported to have said, "It is easy. You just chip away the stone that doesn't look like David."

Although web scraping is unlike marble sculpting in most other respects, you must take a similar attitude when it comes to extracting the information you're seeking from complicated web pages. You can use many techniques to chip away the content that doesn't look like the content that you're searching for, until you arrive at the information you're seeking. In this chapter, you'll take look at parsing complicated HTML pages in order to extract only the information you're looking for.

You Don't Always Need a Hammer

It can be tempting, when faced with a Gordian knot of tags, to dive right in and use multiline statements to try to extract your information. However, keep in mind that layering the techniques used in this section with reckless abandon can lead to code that is difficult to debug, fragile, or both. Before getting started, let's take a look at some of the ways you can avoid altogether the need for advanced HTML parsing!

Let's say you have some target content. Maybe it's a name, statistic, or block of text. Maybe it's buried 20 tags deep in an HTML mush with no helpful tags or HTML attributes to be found. Let's say you decide to throw caution to the wind and write something like the following line to attempt extraction:

```
bs.find_all('table')[4].find_all('tr')[2].find('td').find_all('div')[1].find('a')
```

That doesn't look so great. In addition to the aesthetics of the line, even the slightest change to the website by a site administrator might break your web scraper altogether. What if the site's web developer decides to add another table or another column of data? What if the developer adds another component (with a few `div` tags) to

the top of the page? The preceding line is precarious and depends on the structure of the site never changing.

So what are your options?

- Look for a "Print This Page" link, or perhaps a mobile version of the site that has better-formatted HTML (more on presenting yourself as a mobile device—and receiving mobile site versions—in Chapter 14).
- Look for the information hidden in a JavaScript file. Remember, you might need to examine the imported JavaScript files in order to do this. For example, I once collected street addresses (along with latitude and longitude) off a website in a neatly formatted array by looking at the JavaScript for the embedded Google Map that displayed a pinpoint over each address.
- This is more common for page titles, but the information might be available in the URL of the page itself.
- If the information you are looking for is unique to this website for some reason, you're out of luck. If not, try to think of other sources you could get this information from. Is there another website with the same data? Is this website displaying data that it scraped or aggregated from another website?

Especially when faced with buried or poorly formatted data, it's important not to just start digging and write yourself into a hole that you might not be able to get out of. Take a deep breath and think of alternatives.

If you're certain no alternatives exist, the rest of this chapter explains standard and creative ways of selecting tags based on their position, context, attributes, and contents. The techniques presented here, when used correctly, will go a long way toward writing more stable and reliable web crawlers.

Another Serving of BeautifulSoup

In Chapter 1, you took a quick look at installing and running BeautifulSoup, as well as selecting objects one at a time. In this section, we'll discuss searching for tags by attributes, working with lists of tags, and navigating parse trees.

Nearly every website you encounter contains stylesheets. Although you might think that a layer of styling on websites that is designed specifically for browser and human interpretation might be a bad thing, the advent of CSS is a boon for web scrapers. CSS relies on the differentiation of HTML elements that might otherwise have the exact same markup in order to style them differently. Some tags might look like this:

```
<span class="green"></span>
```

Others look like this:

```
<span class="red"></span>
```

Web scrapers can easily separate these two tags based on their class; for example, they might use BeautifulSoup to grab all the red text but none of the green text. Because CSS relies on these identifying attributes to style sites appropriately, you are almost guaranteed that these class and ID attributes will be plentiful on most modern websites.

Let's create an example web scraper that scrapes the page located at *http://www.pythonscraping.com/pages/warandpeace.html*.

On this page, the lines spoken by characters in the story are in red, whereas the names of characters are in green. You can see the `span` tags, which reference the appropriate CSS classes, in the following sample of the page's source code:

```
<span class="red">Heavens! what a virulent attack!</span> replied
<span class="green">the prince</span>, not in the least disconcerted
by this reception.
```

You can grab the entire page and create a `BeautifulSoup` object with it by using a program similar to the one used in Chapter 1:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup

html = urlopen('http://www.pythonscraping.com/pages/page1.html')
bs = BeautifulSoup(html.read(), 'html.parser')
```

Using this `BeautifulSoup` object, you can use the `find_all` function to extract a Python list of proper nouns found by selecting only the text within `<span class="green"></span>` tags (`find_all` is an extremely flexible function you'll be using a lot later in this book):

```
nameList = bs.findAll('span', {'class':'green'})
for name in nameList:
    print(name.get_text())
```

When run, it should list all the proper nouns in the text, in the order they appear in *War and Peace*. So what's going on here? Previously, you've called `bs.tagName` to get the first occurrence of that tag on the page. Now, you're calling `bs.find_all(tagName, tagAttributes)` to get a list of all of the tags on the page, rather than just the first.

After getting a list of names, the program iterates through all names in the list, and prints `name.get_text()` in order to separate the content from the tags.

When to get_text() and When to Preserve Tags

`.get_text()` strips all tags from the document you are working with and returns a Unicode string containing the text only. For example, if you are working with a large block of text that contains many hyperlinks, paragraphs, and other tags, all those will be stripped away, and you'll be left with a tagless block of text.

Keep in mind that it's much easier to find what you're looking for in a BeautifulSoup object than in a block of text. Calling `.get_text()` should always be the last thing you do, immediately before you print, store, or manipulate your final data. In general, you should try to preserve the tag structure of a document as long as possible.

find() and find_all() with BeautifulSoup

BeautifulSoup's `find()` and `find_all()` are the two functions you will likely use the most. With them, you can easily filter HTML pages to find lists of desired tags, or a single tag, based on their various attributes.

The two functions are extremely similar, as evidenced by their definitions in the BeautifulSoup documentation:

```
find_all(tag, attributes, recursive, text, limit, keywords)
find(tag, attributes, recursive, text, keywords)
```

In all likelihood, 95% of the time you will need to use only the first two arguments: `tag` and `attributes`. However, let's take a look at all the arguments in greater detail.

The `tag` argument is one that you've seen before; you can pass a string name of a tag or even a Python list of string tag names. For example, the following returns a list of all the header tags in a document:[1]

```
.find_all(['h1','h2','h3','h4','h5','h6'])
```

The `attributes` argument takes a Python dictionary of attributes and matches tags that contain any one of those attributes. For example, the following function would return *both* the green and red `span` tags in the HTML document:

```
.find_all('span', {'class':{'green', 'red'}})
```

The `recursive` argument is a boolean. How deeply into the document do you want to go? If `recursive` is set to `True`, the `find_all` function looks into children, and child-

1 If you're looking to get a list of all h<*some_level*> tags in the document, there are more succinct ways of writing this code to accomplish the same thing. We'll take a look at other ways of approaching these types of problems in the section reg_expressions.

ren's children, for tags that match your parameters. If it is `False`, it will look only at the top-level tags in your document. By default, `find_all` works recursively (`recursive` is set to `True`); it's generally a good idea to leave this as is, unless you really know what you need to do and performance is an issue.

The `text` argument is unusual in that it matches based on the text content of the tags, rather than properties of the tags themselves. For instance, if you want to find the number of times "the prince" is surrounded by tags on the example page, you could replace your `.find_all()` function in the previous example with the following lines:

```
nameList = bs.find_all(text='the prince')
print(len(nameList))
```

The output of this is 7.

The `limit` argument, of course, is used only in the `find_all` method; `find` is equivalent to the same `find_all` call, with a limit of 1. You might set this if you're interested only in retrieving the first *x* items from the page. Be aware, however, that this gives you the first items on the page in the order that they occur, not necessarily the first ones that you want.

The `keyword` argument allows you to select tags that contain a particular attribute or set of attributes. For example:

```
title = bs.find_all(id='title', class_='text')
```

This returns the first tag with the word "text" in the `class_` attribute and "title" in the `id` attribute. Note that, by convention, each value for an `id` should be used only once on the page. Therefore, in practice, a line like this may not be particularly useful, and should be equivalent to the following:

```
title = bs.find(id='title')
```

Keyword Arguments and "Class"

The `keyword` argument can be helpful in some situations. However, it is technically redundant as a BeautifulSoup feature. Keep in mind that anything that can be done with `keyword` can also be accomplished using techniques covered later in this chapter (see regular_express and lambda_express).

For instance, the following two lines are identical:

```
bs.find_all(id='text')
bs.find_all('', {'id':'text'})
```

In addition, you might occasionally run into problems using `keyword`, most notably when searching for elements by their `class` attribute, because `class` is a protected keyword in Python. That is, `class` is a reserved word in Python that cannot be used as a variable or argument name (no relation to the `BeautifulSoup.find_all()`

`keyword` argument, previously discussed).[2] For example, if you try the following call, you'll get a syntax error due to the nonstandard use of `class`:

```
bs.find_all(class='green')
```

Instead, you can use BeautifulSoup's somewhat clumsy solution, which involves adding an underscore:

```
bs.find_all(class_='green')
```

Alternatively, you can enclose `class` in quotes:

```
bs.find_all('', {'class':'green'})
```

At this point, you might be asking yourself, "But wait, don't I already know how to get a tag with a list of attributes by passing attributes to the function in a dictionary list?"

Recall that passing a list of tags to `.find_all()` via the attributes list acts as an "or" filter (it selects a list of all tags that have `tag1`, `tag2`, or `tag3`...). If you have a lengthy list of tags, you can end up with a lot of stuff you don't want. The `keyword` argument allows you to add an additional "and" filter to this.

Other BeautifulSoup Objects

So far in the book, you've seen two types of objects in the BeautifulSoup library:

`BeautifulSoup` *objects*
: Instances seen in previous code examples as the variable `bs`

`Tag` *objects*
: Retrieved in lists, or retrieved individually by calling `find` and `find_all` on a `BeautifulSoup` object, or drilling down, as follows:

```
bs.div.h1
```

However, there are two more objects in the library that, although less commonly used, are still important to know about:

`NavigableString` *objects*
: Used to represent text within tags, rather than the tags themselves (some functions operate on and produce `NavigableStrings`, rather than tag objects).

`Comment` *object*
: Used to find HTML comments in comment tags, `<!--like this one-->`.

2 The Python Language Reference provides a complete list of protected keywords.

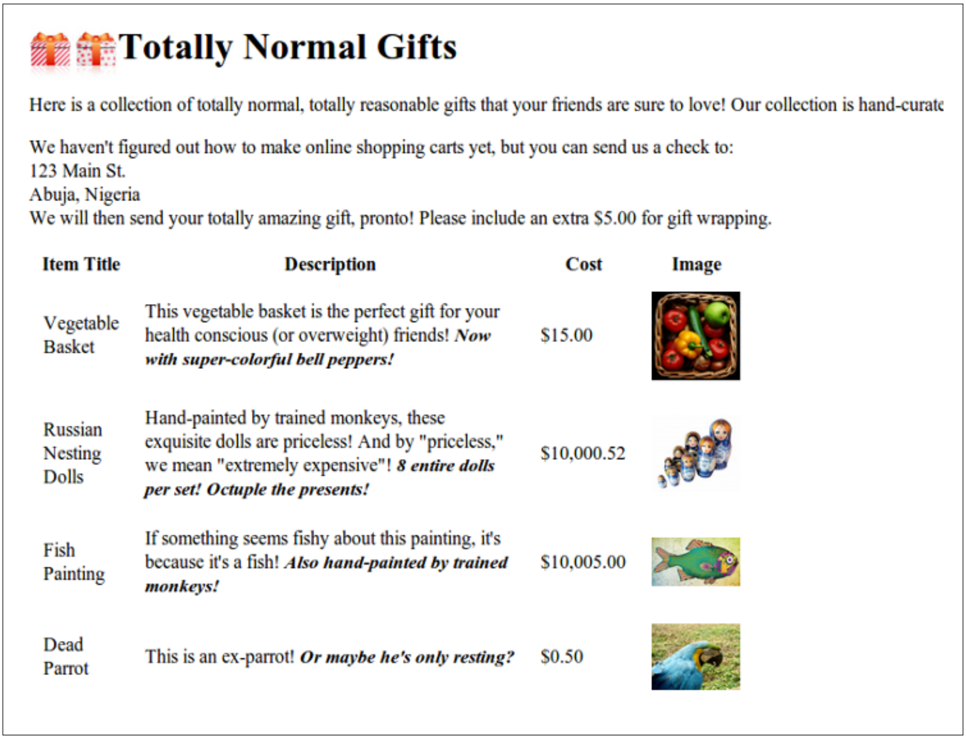
These four objects are the only objects you will ever encounter in the BeautifulSoup library (at the time of this writing).

Navigating Trees

The `find_all` function is responsible for finding tags based on their name and attributes. But what if you need to find a tag based on its location in a document? That's where tree navigation comes in handy. In Chapter 1, you looked at navigating a BeautifulSoup tree in a single direction:

```
bs.tag.subTag.anotherSubTag
```

Now let's look at navigating up, across, and diagonally through HTML trees. You'll use our highly questionable online shopping site at *http://www.pythonscraping.com/pages/page3.html*, as an example page for scraping, as shown in Figure 2-1.



Totally Normal Gifts

Here is a collection of totally normal, totally reasonable gifts that your friends are sure to love! Our collection is hand-curate

We haven't figured out how to make online shopping carts yet, but you can send us a check to:
123 Main St.
Abuja, Nigeria
We will then send your totally amazing gift, pronto! Please include an extra $5.00 for gift wrapping.

Item Title	Description	Cost	Image
Vegetable Basket	This vegetable basket is the perfect gift for your health conscious (or overweight) friends! ***Now with super-colorful bell peppers!***	$15.00	
Russian Nesting Dolls	Hand-painted by trained monkeys, these exquisite dolls are priceless! And by "priceless," we mean "extremely expensive"! ***8 entire dolls per set! Octuple the presents!***	$10,000.52	
Fish Painting	If something seems fishy about this painting, it's because it's a fish! ***Also hand-painted by trained monkeys!***	$10,005.00	
Dead Parrot	This is an ex-parrot! ***Or maybe he's only resting?***	$0.50	

Figure 2-1. Screenshot from http://www.pythonscraping.com/pages/page3.html

The HTML for this page, mapped out as a tree (with some tags omitted for brevity), looks like this:

- HTML
  - — `body`
    - — `div.wrapper`
      - — `h1`
      - — `div.content`
      - — `table#giftList`
        - — `tr`
          - — `th`
          - — `th`
          - — `th`
          - — `th`
        - — `tr.gift#gift1`
          - — `td`
          - — `td`
            - — `span.excitingNote`
          - — `td`
          - — `td`
            - — `img`
        - — ...table rows continue...
      - — `div.footer`

You will use this same HTML structure as an example in the next few sections.

Dealing with children and other descendants

In computer science and some branches of mathematics, you often hear about horrible things done to children: moving them, storing them, removing them, and even killing them. Fortunately, this section focuses only on selecting them!

In the BeautifulSoup library, as well as many other libraries, there is a distinction drawn between *children* and *descendants*: much like in a human family tree, children are always exactly one tag below a parent, whereas descendants can be at any level in the tree below a parent. For example, the `tr` tags are children of the `table` tag, whereas `tr`, `th`, `td`, `img`, and `span` are all descendants of the `table` tag (at least in our example page). All children are descendants, but not all descendants are children.

In general, BeautifulSoup functions always deal with the descendants of the current tag selected. For instance, `bs.body.h1` selects the first `h1` tag that is a descendant of the `body` tag. It will not find tags located outside the body.

Similarly, `bs.div.find_all('img')` will find the first `div` tag in the document, and then retrieve a list of all `img` tags that are descendants of that `div` tag.

If you want to find only descendants that are children, you can use the `.children` tag:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup

html = urlopen('http://www.pythonscraping.com/pages/page3.html')
bs = BeautifulSoup(html, 'html.parser')

for child in bs.find('table',{'id':'giftList'}).children:
    print(child)
```

This code prints the list of product rows in the `giftList` table, including the initial row of column labels. If you were to write it using the `descendants()` function instead of the `children()` function, about two dozen tags would be found within the table and printed, including `img` tags, `span` tags, and individual `td` tags. It's definitely important to differentiate between children and descendants!

Dealing with siblings

The BeautifulSoup `next_siblings()` function makes it trivial to collect data from tables, especially ones with title rows:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup

html = urlopen('http://www.pythonscraping.com/pages/page3.html')
bs = BeautifulSoup(html, 'html.parser')

for sibling in bs.find('table', {'id':'giftList'}).tr.next_siblings:
    print(sibling)
```

The output of this code is to print all rows of products from the product table, except for the first title row. Why does the title row get skipped? Objects cannot be siblings with themselves. Anytime you get siblings of an object, the object itself will not be included in the list. As the name of the function implies, it calls *next* siblings only. If you were to select a row in the middle of the list, for example, and call `next_siblings` on it, only the subsequent siblings would be returned. So, by selecting the title row and calling `next_siblings`, you can select all the rows in the table, without selecting the title row itself.

Make Selections Specific

The preceding code will work just as well, if you select `bs.table.tr` or even just `bs.tr` in order to select the first row of the table. However, in the code, I go through all of the trouble of writing everything out in a longer form:

```
bs.find('table',{'id':'giftList'}).tr
```

Even if it looks like there's just one table (or other target tag) on the page, it's easy to miss things. In addition, page layouts change all the time. What was once the first of its kind on the page might someday be the second or third tag of that type found on the page. To make your scrapers more robust, it's best to be as specific as possible when making tag selections. Take advantage of tag attributes when they are available.

As a complement to `next_siblings`, the `previous_siblings` function can often be helpful if there is an easily selectable tag at the end of a list of sibling tags that you would like to get.

And, of course, there are the `next_sibling` and `previous_sibling` functions, which perform nearly the same function as `next_siblings` and `previous_siblings`, except they return a single tag rather than a list of them.

Dealing with parents

When scraping pages, you will likely discover that you need to find parents of tags less frequently than you need to find their children or siblings. Typically, when you look at HTML pages with the goal of crawling them, you start by looking at the top layer of tags, and then figure out how to drill your way down into the exact piece of data that you want. Occasionally, however, you can find yourself in odd situations that require BeautifulSoup's parent-finding functions, `.parent` and `.parents`. For example:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup

html = urlopen('http://www.pythonscraping.com/pages/page3.html')
bs = BeautifulSoup(html, 'html.parser')
print(bs.find('img',
              {'src':'../img/gifts/img1.jpg'})
      .parent.previous_sibling.get_text())
```

This code will print the price of the object represented by the image at the location *../img/gifts/img1.jpg* (in this case, the price is $15.00).

How does this work? The following diagram represents the tree structure of the portion of the HTML page you are working with, with numbered steps:

- <tr>
  - td
  - td
  - td ❸
    - "$15.00" ❹
  - td ❷
    - <img src="../img/gifts/img1.jpg"> ❶

❶ The image tag where `src="../img/gifts/img1.jpg"` is first selected.

❷ You select the parent of that tag (in this case, the `td` tag).

❸ You select the `previous_sibling` of the `td` tag (in this case, the `td` tag that contains the dollar value of the product).

❹ You select the text within that tag, "$15.00."

Regular Expressions

As the old computer science joke goes: "Let's say you have a problem, and you decide to solve it with regular expressions. Well, now you have two problems."

Unfortunately, regular expressions (often shortened to *regex*) are often taught using large tables of random symbols, strung together to look like a lot of nonsense. This tends to drive people away, and later they get out into the workforce and write needlessly complicated searching and filtering functions, when all they needed was a one-line regular expression in the first place!

Fortunately for you, regular expressions are not all that difficult to get up and running with quickly, and can easily be learned by looking at and experimenting with a few simple examples.

Regular expressions are so called because they are used to identify regular strings; they can definitively say, "Yes, this string you've given me follows the rules, and I'll return it," or "This string does not follow the rules, and I'll discard it." This can be exceptionally handy for quickly scanning large documents to look for strings that look like phone numbers or email addresses.

Notice that I used the phrase *regular string*. What is a regular string? It's any string that can be generated by a series of linear rules,[3] such as these:

1. Write the letter *a* at least once.
2. Append to this the letter *b* exactly five times.
3. Append to this the letter *c* any even number of times.
4. Write either the letter *d* or *e* at the end.

Strings that follow these rules are *aaaabbbbbccccd*, *aabbbbbcce*, and so on (there are an infinite number of variations).

Regular expressions are merely a shorthand way of expressing these sets of rules. For instance, here's the regular expression for the series of steps just described:

```
aa*bbbbb(cc)*(d|e)
```

This string might seem a little daunting at first, but it becomes clearer when you break it into its components:

*aa**
: The letter *a* is written, followed by *a** (read as *a star*), which means "any number of *a*s, including 0 of them." In this way, you can guarantee that the letter *a* is written at least once.

bbbbb
: No special effects here—just five *b*s in a row.

*(cc)**
: Any even number of things can be grouped into pairs, so in order to enforce this rule about even things, you can write two *c*s, surround them in parentheses, and write an asterisk after it, meaning that you can have any number of *pairs* of *c*s (note that this can mean 0 pairs, as well).

(d|e)
: Adding a bar in the middle of two expressions means that it can be "this thing *or* that thing." In this case, you are saying "add a *d or* an *e*." In this way, you can guarantee that there is exactly one of either of these two characters.

3 You might be asking yourself, "Are there 'irregular' expressions?" Nonregular expressions are beyond the scope of this book, but they encompass strings such as "write a prime number of *a*s, followed by exactly twice that number of *b*s" or "write a palindrome." It's impossible to identify strings of this type with a regular expression. Fortunately, I've never been in a situation where my web scraper needed to identify these kinds of strings.

Experimenting with RegEx

When learning how to write regular expressions, it's critical to play around with them and get a feel for how they work. If you don't feel like firing up a code editor, writing a few lines, and running your program in order to see whether a regular expression works as expected, you can go to a website such as Regex Pal and test your regular expressions on the fly.

Table 2-1 lists commonly used regular expression symbols, with brief explanations and examples. This list is by no means complete, and as mentioned before, you might encounter slight variations from language to language. However, these 12 symbols are the most commonly used regular expressions in Python, and can be used to find and collect almost any string type.

Table 2-1. Commonly used regular expression symbols

<table>
<tr><th>Symbol(s)</th><th>Meaning</th><th>Example</th><th>Example matches</th></tr>
<tr><td>*</td><td>Matches the preceding character, subexpression, or bracketed character, 0 or more times.</td><td>a*b*</td><td>aaaaaaaa, aaabbbbb, bbbbbb</td></tr>
<tr><td>+</td><td>Matches the preceding character, subexpression, or bracketed character, 1 or more times.</td><td>a+b+</td><td>aaaaaaaab, aaabbbbb, abbbbbb</td></tr>
<tr><td>[]</td><td>Matches any character within the brackets (i.e., "Pick any one of these things").</td><td>[A-Z]*</td><td>APPLE, CAPITALS, QWERTY</td></tr>
<tr><td>()</td><td>A grouped subexpression (these are evaluated first, in the "order of operations" of regular expressions).</td><td>(a*b)*</td><td>aaabaab, abaaab, ababaaaaab</td></tr>
<tr><td>{m, n}</td><td>Matches the preceding character, subexpression, or bracketed character between m and n times (inclusive).</td><td>a{2,3}b{2,3}</td><td>aabbb, aaabbb, aabb</td></tr>
<tr><td>[^]</td><td>Matches any single character that is not in the brackets.</td><td>[^A-Z]*</td><td>apple, lowercase, qwerty</td></tr>
<tr><td>|</td><td>Matches any character, string of characters, or subexpression, separated by the I (note that this is a vertical bar, or pipe, not a capital i).</td><td>b(a|i|e)d</td><td>bad, bid, bed</td></tr>
<tr><td>.</td><td>Matches any single character (including symbols, numbers, a space, etc.).</td><td>b.d</td><td>bad, bzd, b$d, b d</td></tr>
<tr><td>^</td><td>Indicates that a character or subexpression occurs at the beginning of a string.</td><td>^a</td><td>apple, asdf, a</td></tr>
<tr><td>\</td><td>An escape character (this allows you to use special characters as their literal meanings).</td><td>\. \| \\</td><td>. | \</td></tr>
<tr><td>$</td><td>Often used at the end of a regular expression, it means "match this up to the end of the string." Without it, every regular expression has a de facto ".*" at the end of it, accepting strings where only the first part of the string matches. This can be thought of as analogous to the ^ symbol.</td><td>[A-Z]*[a-z]*$</td><td>ABCabc, zzzyx, Bob</td></tr>
</table>

Symbol(s)	Meaning	Example	Example matches
?!	"Does not contain." This odd pairing of symbols, immediately preceding a character (or regular expression), indicates that that character should not be found in that specific place in the larger string. This can be tricky to use; after all, the character might be found in a different part of the string. If trying to eliminate a character entirely, use in conjunction with a ^ and $ at either end.	^((?![A-Z]).)*$	no-caps-here, $ymb0ls a4e f!ne

One classic example of regular expressions can be found in the practice of identifying email addresses. Although the exact rules governing email addresses vary slightly from mail server to mail server, we can create a few general rules. The corresponding regular expression for each of these rules is shown in the second column:

Rule 1
: The first part of an email address contains at least one of the following: uppercase letters, lowercase letters, the numbers 0–9, periods (.), plus signs (+), or underscores (_).

[A-Za-z0-9\._+]+
: The regular expression shorthand is pretty smart. For example, it knows that "A-Z" means "any uppercase letter, A through Z." By putting all these possible sequences and symbols in brackets (as opposed to parentheses), you are saying, "This symbol can be any one of these things we've listed in the brackets." Note also that the + sign means "these characters can occur as many times as they want to, but must occur at least once."

Rule 2
: After this, the email address contains the @ symbol.

@
: This is fairly straightforward: the @ symbol must occur in the middle, and it must occur exactly once.

Rule 3
: The email address then must contain at least one uppercase or lowercase letter.

[A-Za-z]+
: You may use only letters in the first part of the domain name, after the @ symbol. Also, there must be at least one character.

Rule 4
: This is followed by a period (.).

\.
: You must include a period (.) before the domain name. The backspace is used here as an escape character.

Rule 5 Finally, the email address ends with *com*, *org*, *edu*, or *net* (in reality, there are many possible top-level domains, but these four should suffice for the sake of example).	***(com|org|edu|net)*** This lists the possible sequences of letters that can occur after the period in the second part of an email address.

By concatenating all of the rules, you arrive at this regular expression:

```
[A-Za-z0-9\._+]+@[A-Za-z]+\.(com|org|edu|net)
```

When attempting to write any regular expression from scratch, it's best to first make a list of steps that concretely outlines what your target string looks like. Pay attention to edge cases. For instance, if you're identifying phone numbers, are you considering country codes and extensions?

Regular Expressions: Not Always Regular!

The standard version of regular expressions (the one covered in this book and used by Python and BeautifulSoup) is based on syntax used by Perl. Most modern programming languages use this or one similar to it. Be aware, however, that if you are using regular expressions in another language, you might encounter problems. Even some modern languages, such as Java, have slight differences in the way they handle regular expressions. When in doubt, read the docs!

Regular Expressions and BeautifulSoup

If the previous section on regular expressions seemed a little disjointed from the mission of this book, here's where it all ties together. BeautifulSoup and regular expressions go hand in hand when it comes to scraping the web. In fact, most functions that take in a string argument (e.g., `find(id="aTagIdHere")`) will also take in a regular expression just as well.

Let's take a look at some examples, scraping the page found at *http://www.python-scraping.com/pages/page3.html*.

Notice that the site has many product images, which take the following form:

```
<img src="../img/gifts/img3.jpg">
```

If you wanted to grab URLs to all of the product images, it might seem fairly straightforward at first: just grab all the image tags by using `.find_all("img")`, right? But there's a problem. In addition to the obvious "extra" images (e.g., logos), modern web-

sites often have hidden images, blank images used for spacing and aligning elements, and other random image tags you might not be aware of. Certainly, you can't count on the only images on the page being product images.

Let's also assume that the layout of the page might change, or that, for whatever reason, you don't want to depend on the *position* of the image in the page in order to find the correct tag. This might be the case when you are trying to grab specific elements or pieces of data that are scattered randomly throughout a website. For instance, a featured product image might appear in a special layout at the top of some pages, but not others.

The solution is to look for something identifying about the tag itself. In this case, you can look at the file path of the product images:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re

html = urlopen('http://www.pythonscraping.com/pages/page3.html')
bs = BeautifulSoup(html, 'html.parser')
images = bs.find_all('img',
    {'src':re.compile('\.\.\/img\/gifts/img.*\.jpg')})
for image in images:
    print(image['src'])
```

This prints only the relative image paths that start with *../img/gifts/img* and end in *.jpg*, the output of which is the following:

```
../img/gifts/img1.jpg
../img/gifts/img2.jpg
../img/gifts/img3.jpg
../img/gifts/img4.jpg
../img/gifts/img6.jpg
```

A regular expression can be inserted as any argument in a BeautifulSoup expression, allowing you a great deal of flexibility in finding target elements.

Accessing Attributes

So far, you've looked at how to access and filter tags and access content within them. However, often in web scraping you're not looking for the content of a tag; you're looking for its attributes. This becomes especially useful for tags such as `a`, where the URL it is pointing to is contained within the `href` attribute; or the `img` tag, where the target image is contained within the `src` attribute.

With tag objects, a Python list of attributes can be automatically accessed by calling this:

```
myTag.attrs
```

Keep in mind that this literally returns a Python dictionary object, which makes retrieval and manipulation of these attributes trivial. The source location for an image, for example, can be found using the following line:

```
myImgTag.attrs['src']
```

Lambda Expressions

If you have a formal education in computer science, you probably learned about lambda expressions once in school and then never used them again. If you don't, they might be unfamiliar to you (or familiar only as "that thing I've been meaning to learn at some point"). This section doesn't go deeply into these types of functions, but does show how they can be useful in web scraping.

Essentially, a *lambda expression* is a function that is passed into another function as a variable; instead of defining a function as f(x, y), you may define a function as f(g(x), y) or even f(g(x), h(x)).

BeautifulSoup allows you to pass certain types of functions as parameters into the `find_all` function.

The only restriction is that these functions must take a tag object as an argument and return a boolean. Every tag object that BeautifulSoup encounters is evaluated in this function, and tags that evaluate to `True` are returned, while the rest are discarded.

For example, the following retrieves all tags that have exactly two attributes:

```
bs.find_all(lambda tag: len(tag.attrs) == 2)
```

Here, the function that you are passing as the argument is `len(tag.attrs) == 2`. Where this is `True`, the `find_all` function will return the tag. That is, it will find tags with two attributes, such as the following:

```
<div class="body" id="content"></div>
<span style="color:red" class="title"></span>
```

Lambda functions are so useful you can even use them to replace existing BeautifulSoup functions:

```
bs.find_all(lambda tag: tag.get_text() ==
    'Or maybe he\'s only resting?')
```

This can also be accomplished without a lambda function:

```
bs.find_all('', text='Or maybe he\'s only resting?')
```

However, if you remember the syntax for the lambda function, and how to access tag properties, you may never need to remember any other BeautifulSoup syntax again!

Because the provided lambda function can be any function that returns a `True` or `False` value, you can even combine them with regular expressions to find tags with an attribute matching a certain string pattern.

CHAPTER 3
Writing Web Crawlers

So far, you've seen single static pages with somewhat artificial canned examples. In this chapter, you'll start looking at real-world problems, with scrapers traversing multiple pages and even multiple sites.

Web crawlers are called such because they crawl across the web. At their core is an element of recursion. They must retrieve page contents for a URL, examine that page for another URL, and retrieve *that* page, ad infinitum.

Beware, however: just because you can crawl the web doesn't mean that you always should. The scrapers used in previous examples work great in situations where all the data you need is on a single page. With web crawlers, you must be extremely conscientious of how much bandwidth you are using and make every effort to determine whether there's a way to make the target server's load easier.

Traversing a Single Domain

Even if you haven't heard of Six Degrees of Wikipedia, you've almost certainly heard of its namesake, Six Degrees of Kevin Bacon. In both games, the goal is to link two unlikely subjects (in the first case, Wikipedia articles that link to each other, and in the second case, actors appearing in the same film) by a chain containing no more than six total (including the two original subjects).

For example, Eric Idle appeared in *Dudley Do-Right* with Brendan Fraser, who appeared in *The Air I Breathe* with Kevin Bacon.[1] In this case, the chain from Eric Idle to Kevin Bacon is only three subjects long.

1 Thanks to The Oracle of Bacon for satisfying my curiosity about this particular chain.

In this section, you'll begin a project that will become a Six Degrees of Wikipedia solution finder: You'll be able to take the Eric Idle page and find the fewest number of link clicks that will take you to the Kevin Bacon page.

But What About Wikipedia's Server Load?

According to the Wikimedia Foundation (the parent organization behind Wikipedia), the site's web properties receive approximately 2,500 hits per *second*, with more than 99% of them to the Wikipedia domain (see the "Traffic Volume" section of the "Wikimedia in Figures" page). Because of the sheer volume of traffic, your web scrapers are unlikely to have any noticeable impact on Wikipedia's server load. However, if you run the code samples in this book extensively, or create your own projects that scrape Wikipedia, I encourage you to make a tax-deductible donation to the Wikimedia Foundation—not just to offset your server load, but also to help make education resources available for everyone else.

Also keep in mind that if you plan on doing a large project involving data from Wikipedia, you should check to make sure that data isn't already available from the Wikipedia API. Wikipedia is often used as a website to demonstrate scrapers and crawlers because it has a simple HTML structure and is relatively stable. However, its APIs often make this same data more efficiently accessible.

You should already know how to write a Python script that retrieves an arbitrary Wikipedia page and produces a list of links on that page:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup

html = urlopen('http://en.wikipedia.org/wiki/Kevin_Bacon')
bs = BeautifulSoup(html, 'html.parser')
for link in bs.find_all('a'):
    if 'href' in link.attrs:
        print(link.attrs['href'])
```

If you look at the list of links produced, you'll notice that all the articles you'd expect are there: "Apollo 13," "Philadelphia," "Primetime Emmy Award," and so on. However, there are some things that you don't want as well:

```
//wikimediafoundation.org/wiki/Privacy_policy
//en.wikipedia.org/wiki/Wikipedia:Contact_us
```

In fact, Wikipedia is full of sidebar, footer, and header links that appear on every page, along with links to the category pages, talk pages, and other pages that do not contain different articles:

```
/wiki/Category:Articles_with_unsourced_statements_from_April_2014
/wiki/Talk:Kevin_Bacon
```

Recently a friend of mine, while working on a similar Wikipedia-scraping project, mentioned he had written a large filtering function, with more than 100 lines of code, in order to determine whether an internal Wikipedia link was an article page. Unfortunately, he had not spent much time upfront trying to find patterns between "article links" and "other links," or he might have discovered the trick. If you examine the links that point to article pages (as opposed to other internal pages), you'll see that they all have three things in common:

- They reside within the `div` with the `id` set to `bodyContent`.
- The URLs do not contain colons.
- The URLs begin with */wiki/*.

You can use these rules to revise the code slightly to retrieve only the desired article links by using the regular expression `^(/wiki/)((?!:).)*$")`:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re

html = urlopen('http://en.wikipedia.org/wiki/Kevin_Bacon')
bs = BeautifulSoup(html, 'html.parser')
for link in bs.find('div', {'id':'bodyContent'}).find_all(
    'a', href=re.compile('^(/wiki/)((?!:).)*$')):
    if 'href' in link.attrs:
        print(link.attrs['href'])
```

If you run this, you should see a list of all article URLs that the Wikipedia article on Kevin Bacon links to.

Of course, having a script that finds all article links in one, hardcoded Wikipedia article, while interesting, is fairly useless in practice. You need to be able to take this code and transform it into something more like the following:

- A single function, `getLinks`, that takes in a Wikipedia article URL of the form `/wiki/<Article_Name>` and returns a list of all linked article URLs in the same form.
- A main function that calls `getLinks` with a starting article, chooses a random article link from the returned list, and calls `getLinks` again, until you stop the program or until no article links are found on the new page.

Here is the complete code that accomplishes this:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import datetime
import random
import re
```

```
random.seed(datetime.datetime.now())
def getLinks(articleUrl):
    html = urlopen('http://en.wikipedia.org{}'.format(articleUrl))
    bs = BeautifulSoup(html, 'html.parser')
    return bs.find('div', {'id':'bodyContent'}).find_all('a',
         href=re.compile('^(/wiki/)((?!:).)*$'))

links = getLinks('/wiki/Kevin_Bacon')
while len(links) > 0:
    newArticle = links[random.randint(0, len(links)-1)].attrs['href']
    print(newArticle)
    links = getLinks(newArticle)
```

The first thing the program does, after importing the needed libraries, is set the random-number generator seed with the current system time. This practically ensures a new and interesting random path through Wikipedia articles every time the program is run.

Pseudorandom Numbers and Random Seeds

The previous example used Python's random-number generator to select an article at random on each page in order to continue a random traversal of Wikipedia. However, random numbers should be used with caution.

Although computers are great at calculating correct answers, they're terrible at making things up. For this reason, random numbers can be a challenge. Most random-number algorithms strive to produce an evenly distributed and hard-to-predict sequence of numbers, but a "seed" number is needed to give these algorithms something to work with initially. The exact same seed will produce the exact same sequence of "random" numbers every time, so for this reason I've used the system clock as a starter for producing new sequences of random numbers, and, thus, new sequences of random articles. This makes the program a little more exciting to run.

For the curious, the Python pseudorandom number generator is powered by the *Mersenne Twister algorithm*. While it produces random numbers that are difficult to predict and uniformly distributed, it is slightly processor intensive. Random numbers this good don't come cheap!

Next, the program defines the `getLinks` function, which takes in an article URL of the form `/wiki/...`, prepends the Wikipedia domain name, `http://en.wikipedia.org`, and retrieves the `BeautifulSoup` object for the HTML at that domain. It then extracts a list of article link tags, based on the parameters discussed previously, and returns them.

The main body of the program begins with setting a list of article link tags (the `links` variable) to the list of links in the initial page: *https://en.wikipedia.org/wiki/*

Kevin_Bacon. It then goes into a loop, finding a random article link tag in the page, extracting the `href` attribute from it, printing the page, and getting a new list of links from the extracted URL.

Of course, there's a bit more to solving a Six Degrees of Wikipedia problem than building a scraper that goes from page to page. You must also be able to store and analyze the resulting data. For a continuation of the solution to this problem, see Chapter 6.

> **Handle Your Exceptions!**
>
> Although these code examples omit most exception handling for the sake of brevity, be aware that many potential pitfalls could arise. What if Wikipedia changes the name of the `bodyContent` tag, for example? When the program attempts to extract the text from the tag, it throws an `AttributeError`.
>
> So although these scripts might be fine to run as closely watched examples, autonomous production code requires far more exception handling than can fit into this book. Look back to Chapter 1 for more information about this.

Crawling an Entire Site

In the previous section, you took a random walk through a website, going from link to link. But what if you need to systematically catalog or search every page on a site? Crawling an entire site, especially a large one, is a memory-intensive process that is best suited to applications for which a database to store crawling results is readily available. However, you can explore the behavior of these types of applications without running them full-scale. To learn more about running these applications by using a database, see Chapter 6.

The Dark and Deep Webs

You've likely heard the terms *deep web*, *dark web*, or *hidden web* being thrown around a lot, especially in the media lately. What do they mean?

The *deep web* is any part of the web that's not part of the *surface web*.[2] The surface is part of the internet that is indexed by search engines. Estimates vary widely, but the deep web almost certainly makes up about 90% of the internet. Because Google can't do things like submit forms, find pages that haven't been linked to by a top-level

2 See "Exploring a 'Deep Web' that Google Can't Grasp" by Alex Wright.

domain, or investigate sites where *robots.txt* prohibits it, the surface web stays relatively small.

The *dark web*, also known as the *darknet*, is another beast entirely.[3] It is run over the existing network hardware infrastructure but uses Tor, or another client, with an application protocol that runs on top of HTTP, providing a secure channel to exchange information. Although it is possible to scrape the dark web, just as you'd scrape any other website, doing so is outside the scope of this book.

Unlike the dark web, the deep web is relatively easy to scrape. Many tools in this book will teach you how to crawl and scrape information from many places that Google bots can't go.

When might crawling an entire website be useful, and when might it be harmful? Web scrapers that traverse an entire site are good for many things, including the following:

Generating a site map
: A few years ago, I was faced with a problem: an important client wanted an estimate for a website redesign, but did not want to provide my company with access to the internals of their current content management system, and did not have a publicly available site map. I was able to use a crawler to cover the entire site, gather all internal links, and organize the pages into the actual folder structure used on the site. This allowed me to quickly find sections of the site I wasn't even aware existed, and accurately count how many page designs would be required and how much content would need to be migrated.

Gathering data
: Another client of mine wanted to gather articles (stories, blog posts, news articles, etc.) in order to create a working prototype of a specialized search platform. Although these website crawls didn't need to be exhaustive, they did need to be fairly expansive (we were interested in getting data from only a few sites). I was able to create crawlers that recursively traversed each site and collected only data found on article pages.

The general approach to an exhaustive site crawl is to start with a top-level page (such as the home page), and search for a list of all internal links on that page. Every one of those links is then crawled, and additional lists of links are found on each one of them, triggering another round of crawling.

Clearly, this is a situation that can blow up quickly. If every page has 10 internal links, and a website is 5 pages deep (a fairly typical depth for a medium-size website), then

3 See "Hacker Lexicon: What is the Dark Web?" by Andy Greenberg.

the number of pages you need to crawl is 10^5, or 100,000 pages, before you can be sure that you've exhaustively covered the website. Strangely enough, although "5 pages deep and 10 internal links per page" are fairly typical dimensions for a website, very few websites have 100,000 or more pages. The reason, of course, is that the vast majority of internal links are duplicates.

To avoid crawling the same page twice, it is extremely important that all internal links discovered are formatted consistently, and kept in a running set for easy lookups, while the program is running. A *set* is similar to a list, but elements do not have a specific order, and only unique elements will be stored, which is ideal for our needs. Only links that are "new" should be crawled and searched for additional links:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re

pages = set()
def getLinks(pageUrl):
    global pages
    html = urlopen('http://en.wikipedia.org{}'.format(pageUrl))
    bs = BeautifulSoup(html, 'html.parser')
    for link in bs.find_all('a', href=re.compile('^(/wiki/)')):
        if 'href' in link.attrs:
            if link.attrs['href'] not in pages:
                #We have encountered a new page
                newPage = link.attrs['href']
                print(newPage)
                pages.add(newPage)
                getLinks(newPage)
getLinks('')
```

To show you the full effect of how this web crawling business works, I've relaxed the standards of what constitutes an internal link (from previous examples). Rather than limit the scraper to article pages, it looks for all links that begin with */wiki/*, regardless of where they are on the page, and regardless of whether they contain colons. Remember: article pages do not contain colons, but file-upload pages, talk pages, and the like do contain colons in the URL.

Initially, `getLinks` is called with an empty URL. This is translated as "the front page of Wikipedia" as soon as the empty URL is prepended with `http://en.wikipedia.org` inside the function. Then, each link on the first page is iterated through and a check is made to see whether it is in the *global set* of pages (a set of pages that the script has encountered already). If not, it is added to the list, printed to the screen, and the `getLinks` function is called recursively on it.

A Warning Regarding Recursion

This is a warning rarely seen in software books, but I thought you should be aware: if left running long enough, the preceding program will almost certainly crash.

Python has a default recursion limit (the number of times a program can recursively call itself) of 1,000. Because Wikipedia's network of links is extremely large, this program will eventually hit that recursion limit and stop, unless you put in a recursion counter or something to prevent that from happening.

For "flat" sites that are fewer than 1,000 links deep, this method usually works well, with a few unusual exceptions. For instance, I once encountered a bug in a dynamically generated URL that depended on the address of the current page to write the link on that page. This resulted in infinitely repeating paths like */blogs/blogs.../blogs/blog-post.php*.

For the most part, however, this recursive technique should be fine for any typical website you're likely to encounter.

Collecting Data Across an Entire Site

Web crawlers would be fairly boring if all they did was hop from one page to the other. To make them useful, you need to be able to do something on the page while you're there. Let's look at how to build a scraper that collects the title, the first paragraph of content, and the link to edit the page (if available).

As always, the first step to determine how best to do this is to look at a few pages from the site and determine a pattern. By looking at a handful of Wikipedia pages (both articles and nonarticle pages such as the privacy policy page), the following things should be clear:

- All titles (on all pages, regardless of their status as an article page, an edit history page, or any other page) have titles under `h1` → `span` tags, and these are the only `h1` tags on the page.
- As mentioned before, all body text lives under the `div#bodyContent` tag. However, if you want to get more specific and access just the first paragraph of text, you might be better off using `div#mw-content-text` → `p` (selecting the first paragraph tag only). This is true for all content pages except file pages (for example, *https://en.wikipedia.org/wiki/File:Orbit_of_274301_Wikipedia.svg*), which do not have sections of content text.

- Edit links occur only on article pages. If they occur, they will be found in the `li#ca-edit` tag, under `li#ca-edit` → `span` → `a`.

By modifying our basic crawling code, you can create a combination crawler/data-gathering (or, at least, data-printing) program:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re

pages = set()
def getLinks(pageUrl):
    global pages
    html = urlopen('http://en.wikipedia.org{}'.format(pageUrl))
    bs = BeautifulSoup(html, 'html.parser')
    try:
        print(bs.h1.get_text())
        print(bs.find(id ='mw-content-text').find_all('p')[0])
        print(bs.find(id='ca-edit').find('span')
             .find('a').attrs['href'])
    except AttributeError:
        print('This page is missing something! Continuing.')

    for link in bs.find_all('a', href=re.compile('^(/wiki/)')):
        if 'href' in link.attrs:
            if link.attrs['href'] not in pages:
                #We have encountered a new page
                newPage = link.attrs['href']
                print('-'*20)
                print(newPage)
                pages.add(newPage)
                getLinks(newPage)
getLinks('')
```

The `for` loop in this program is essentially the same as it was in the original crawling program (with the addition of printed dashes for clarity, separating the printed content).

Because you can never be entirely sure that all the data is on each page, each `print` statement is arranged in the order that it is likeliest to appear on the site. That is, the `h1` title tag appears on every page (as far as I can tell, at any rate) so you attempt to get that data first. The text content appears on most pages (except for file pages), so that is the second piece of data retrieved. The Edit button appears only on pages in which both titles and text content already exist, but it does not appear on all of those pages.

Different Patterns for Different Needs

Obviously, some dangers are involved with wrapping multiple lines in an exception handler. You cannot tell which line threw the exception, for one thing. Also, if for some reason a page contains an Edit button but no title, the Edit button would never be logged. However, it suffices for many instances in which there is an order of likeliness of items appearing on the site, and inadvertently missing a few data points or keeping detailed logs is not a problem.

You might notice that in this and all the previous examples, you haven't been "collecting" data so much as "printing" it. Obviously, data in your terminal is hard to manipulate. You'll look more at storing information and creating databases in Chapter 5.

Handling Redirects

Redirects allow a web server to point one domain name or URL to a piece of content at a different location. There are two types of redirects:

- Server-side redirects, where the URL is changed before the page is loaded
- Client-side redirects, sometimes seen with a "You will be redirected in 10 seconds" type of message, where the page loads before redirecting to the new one

With server-side redirects, you usually don't have to worry. If you're using the `urllib` library with Python 3.x, it handles redirects automatically! If you're using the requests library, make sure to set the allow-redirects flag to `True`:

```
r = requests.get('http://github.com', allow_redirects=True)
```

Just be aware that, occasionally, the URL of the page you're crawling might not be exactly the URL that you entered the page on.

For more information on client-side redirects, which are performed using JavaScript or HTML, see Chapter 12.

Crawling Across the Internet

Whenever I give a talk on web scraping, someone inevitably asks, "How do you build Google?" My answer is always twofold: "First, you get many billions of dollars so that you can buy the world's largest data warehouses and place them in hidden locations all around the world. Second, you build a web crawler."

When Google started in 1996, it was just two Stanford graduate students with an old server and a Python web crawler. Now that you know how to scrape the web, you officially have the tools you need to become the next tech multibillionaire!

In all seriousness, web crawlers are at the heart of what drives many modern web technologies, and you don't necessarily need a large data warehouse to use them. To do any cross-domain data analysis, you do need to build crawlers that can interpret and store data across the myriad of pages on the internet.

Just as in the previous example, the web crawlers you are going to build will follow links from page to page, building out a map of the web. But this time, they will not ignore external links; they will follow them.

> **Unknown Waters Ahead**
>
> Keep in mind that the code from the next section can go *anywhere* on the internet. If we've learned anything from Six Degrees of Wikipedia, it's that it's entirely possible to go from a site such as *http://www.sesamestreet.org/* to something less savory in just a few hops.
>
> Kids, ask your parents before running this code. For those with sensitive constitutions or with religious restrictions that might prohibit seeing text from a prurient site, follow along by reading the code examples but be careful when running them.

Before you start writing a crawler that follows all outbound links willy-nilly, you should ask yourself a few questions:

- What data am I trying to gather? Can this be accomplished by scraping just a few predefined websites (almost always the easier option), or does my crawler need to be able to discover new websites I might not know about?
- When my crawler reaches a particular website, will it immediately follow the next outbound link to a new website, or will it stick around for a while and drill down into the current website?
- Are there any conditions under which I would not want to scrape a particular site? Am I interested in non-English content?
- How am I protecting myself against legal action if my web crawler catches the attention of a webmaster on one of the sites it runs across? (Check out Chapter 18 for more information on this subject.)

A flexible set of Python functions that can be combined to perform a variety of types of web scraping can be easily written in fewer than 60 lines of code:

```
from urllib.request import urlopen
from urllib.parse import urlparse
from bs4 import BeautifulSoup
import re
import datetime
import random
```

```
pages = set()
random.seed(datetime.datetime.now())

#Retrieves a list of all Internal links found on a page
def getInternalLinks(bs, includeUrl):
    includeUrl = '{}://{}'.format(urlparse(includeUrl).scheme,
        urlparse(includeUrl).netloc)
    internalLinks = []
    #Finds all links that begin with a "/"
    for link in bs.find_all('a',
        href=re.compile('^(/|.*'+includeUrl+')')):
        if link.attrs['href'] is not None:
            if link.attrs['href'] not in internalLinks:
                if(link.attrs['href'].startswith('/')):
                    internalLinks.append(
                        includeUrl+link.attrs['href'])
                else:
                    internalLinks.append(link.attrs['href'])
    return internalLinks

#Retrieves a list of all external links found on a page
def getExternalLinks(bs, excludeUrl):
    externalLinks = []
    #Finds all links that start with "http" that do
    #not contain the current URL
    for link in bs.find_all('a',
        href=re.compile('^(http|www)((?!'+excludeUrl+').)*$')):
        if link.attrs['href'] is not None:
            if link.attrs['href'] not in externalLinks:
                externalLinks.append(link.attrs['href'])
    return externalLinks

def getRandomExternalLink(startingPage):
    html = urlopen(startingPage)
    bs = BeautifulSoup(html, 'html.parser')
    externalLinks = getExternalLinks(bs,
        urlparse(startingPage).netloc)
    if len(externalLinks) == 0:
        print('No external links, looking around the site for one')
        domain = '{}://{}'.format(urlparse(startingPage).scheme,
            urlparse(startingPage).netloc)
        internalLinks = getInternalLinks(bs, domain)
        return getRandomExternalLink(internalLinks[random.randint(0,
                                    len(internalLinks)-1)])
    else:
        return externalLinks[random.randint(0, len(externalLinks)-1)]

def followExternalOnly(startingSite):
    externalLink = getRandomExternalLink(startingSite)
    print('Random external link is: {}'.format(externalLink))
    followExternalOnly(externalLink)
```

```
followExternalOnly('http://oreilly.com')
```

The preceding program starts at *http://oreilly.com* and randomly hops from external link to external link. Here's an example of the output it produces:

```
http://igniteshow.com/
http://feeds.feedburner.com/oreilly/news
http://hire.jobvite.com/CompanyJobs/Careers.aspx?c=q319
http://makerfaire.com/
```

External links are not always guaranteed to be found on the first page of a website. To find external links in this case, a method similar to the one used in the previous crawling example is employed to recursively drill down into a website until it finds an external link.

Figure 3-1 illustrates the operation as a flowchart.

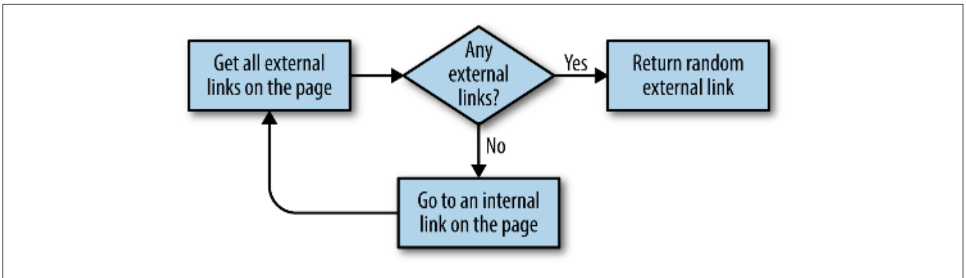


Figure 3-1. Flowchart for our script that crawls through sites on the internet

Don't Put Example Programs into Production

I keep bringing this up, but for the sake of space and readability, the example programs in this book do not always contain the necessary checks and exception handling required for production-ready code. For example, if an external link is not found anywhere on a site that this crawler encounters (unlikely, but it's bound to happen at some point if you run it for long enough), this program will keep running until it hits Python's recursion limit.

One easy way to increase the robustness of this crawler would be to combine it with the connection exception-handling code in Chapter 1. This would allow the code to choose a different URL to go to if an HTTP error or server exception was encountered when retrieving the page.

Before running this code for any serious purpose, make sure that you are putting checks in place to handle potential pitfalls.

The nice thing about breaking up tasks into simple functions such as "find all external links on this page" is that the code can later be easily refactored to perform a different crawling task. For example, if your goal is to crawl an entire site for external links, and make a note of each one, you can add the following function:

```
# Collects a list of all external URLs found on the site
allExtLinks = set()
allIntLinks = set()

def getAllExternalLinks(siteUrl):
    html = urlopen(siteUrl)
    domain = '{}://{}'.format(urlparse(siteUrl).scheme,
        urlparse(siteUrl).netloc)
    bs = BeautifulSoup(html, 'html.parser')
    internalLinks = getInternalLinks(bs, domain)
    externalLinks = getExternalLinks(bs, domain)

    for link in externalLinks:
        if link not in allExtLinks:
            allExtLinks.add(link)
            print(link)
    for link in internalLinks:
        if link not in allIntLinks:
            allIntLinks.add(link)
            getAllExternalLinks(link)

allIntLinks.add('http://oreilly.com')
getAllExternalLinks('http://oreilly.com')
```

This code can be thought of as two loops—one gathering internal links, one gathering external links—working in conjunction with each other. The flowchart looks something like Figure 3-2.

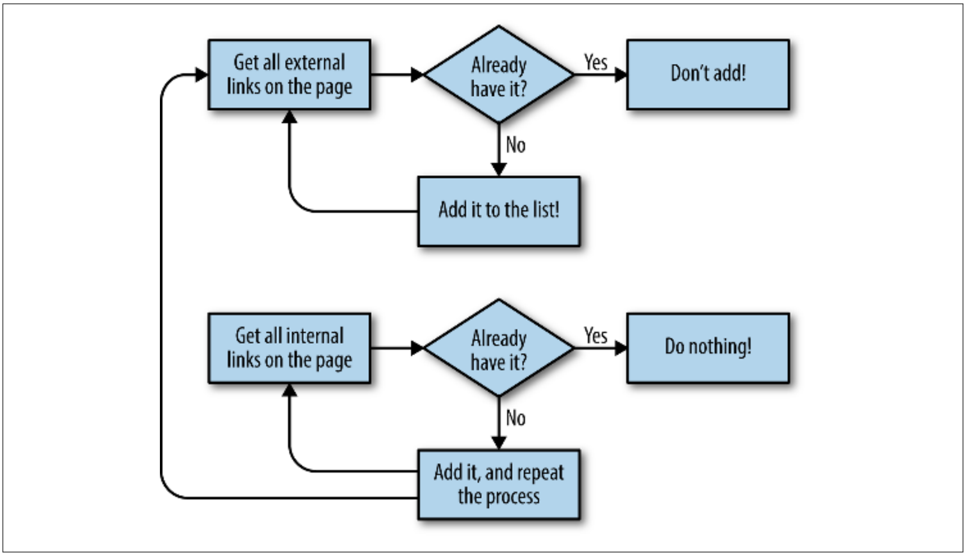


Figure 3-2. Flow diagram for the website crawler that collects all external links

Jotting down or making diagrams of what the code should do before you write the code itself is a fantastic habit to get into, and one that can save you a lot of time and frustration as your crawlers get more complicated.

CHAPTER 4

Web Crawling Models

Writing clean and scalable code is difficult enough when you have control over your data and your inputs. Writing code for web crawlers, which may need to scrape and store a variety of data from diverse sets of websites that the programmer has no control over, often presents unique organizational challenges.

You may be asked to collect news articles or blog posts from a variety of websites, each with different templates and layouts. One website's `h1` tag contains the title of the article, another's `h1` tag contains the title of the website itself, and the article title is in `<span id="title">`.

You may need flexible control over which websites are scraped and how they're scraped, and a way to quickly add new websites or modify existing ones, as fast as possible, without writing multiple lines of code.

You may be asked to scrape product prices from different websites, with the ultimate aim of comparing prices for the same product. Perhaps these prices are in different currencies, and perhaps you'll also need to combine this with external data from some other nonweb source.

Although the applications of web crawlers are nearly endless, large scalable crawlers tend to fall into one of several patterns. By learning these patterns and recognizing the situations they apply to, you can vastly improve the maintainability and robustness of your web crawlers.

This chapter focuses primarily on web crawlers that collect a limited number of "types" of data (such as restaurant reviews, news articles, company profiles) from a variety of websites, and that store these data types as Python objects that read and write from a database.

Planning and Defining Objects

One common trap of web scraping is defining the data that you want to collect based entirely on what's available in front of your eyes. For instance, if you want to collect product data, you may first look at a clothing store and decide that each product you scrape needs to have the following fields:

- Product name
- Price
- Description
- Sizes
- Colors
- Fabric type
- Customer rating

Looking at another website, you find that it has SKUs (stock keeping units, used to track and order items) listed on the page. You definitely want to collect that data as well, even if it doesn't appear on the first site! You add this field:

- Item SKU

Although clothing may be a great start, you also want to make sure you can extend this crawler to other types of products. You start perusing product sections of other websites and decide you also need to collect this information:

- Hardcover/Paperback
- Matte/Glossy print
- Number of customer reviews
- Link to manufacturer

Clearly, this is an unsustainable approach. Simply adding attributes to your product type every time you see a new piece of information on a website will lead to far too many fields to keep track of. Not only that, but every time you scrape a new website, you'll be forced to perform a detailed analysis of the fields the website has and the fields you've accumulated so far, and potentially add new fields (modifying your Python object type and your database structure). This will result in a messy and difficult-to-read dataset that may lead to problems using it.

One of the best things you can do when deciding which data to collect is often to ignore the websites altogether. You don't start a project that's designed to be large and scalable by looking at a single website and saying, "What exists?" but by saying,

"What do I need?" and then finding ways to seek the information that you need from there.

Perhaps what you really want to do is compare product prices among multiple stores and track those product prices over time. In this case, you need enough information to uniquely identify the product, and that's it:

- Product title
- Manufacturer
- Product ID number (if available/relevant)

It's important to note that none of this information is specific to a particular store. For instance, product reviews, ratings, price, and even description are specific to the instance of that product at a particular store. That can be stored separately.

Other information (colors the product comes in, what it's made of) is specific to the product, but may be sparse—it's not applicable to every product. It's important to take a step back and perform a checklist for each item you consider and ask yourself the following questions:

- Will this information help with the project goals? Will it be a roadblock if I don't have it, or is it just "nice to have" but won't ultimately impact anything?
- If it *might* help in the future, but I'm unsure, how difficult will it be to go back and collect the data at a later time?
- Is this data redundant to data I've already collected?
- Does it make logical sense to store the data within this particular object? (As mentioned before, storing a description in a product doesn't make sense if that description changes from site to site for the same product.)

If you do decide that you need to collect the data, it's important to ask a few more questions to then decide how to store and handle it in code:

- Is this data sparse or dense? Will it be relevant and populated in every listing, or just a handful out of the set?
- How large is the data?
- Especially in the case of large data, will I need to regularly retrieve it every time I run my analysis, or only on occasion?
- How variable is this type of data? Will I regularly need to add new attributes, modify types (such as fabric patterns, which may be added frequently), or is it set in stone (shoe sizes)?

Let's say you plan to do some meta analysis around product attributes and prices: for example, the number of pages a book has, or the type of fabric a piece of clothing is made of, and potentially other attributes in the future, correlated to price. You run through the questions and realize that this data is sparse (relatively few products have any one of the attributes), and that you may decide to add or remove attributes frequently. In this case, it may make sense to create a product type that looks like this:

- Product title
- Manufacturer
- Product ID number (if available/relevant)
- Attributes (optional list or dictionary)

And an attribute type that looks like this:

- Attribute name
- Attribute value

This allows you to flexibly add new product attributes over time, without requiring you to redesign your data schema or rewrite code. When deciding how to store these attributes in the database, you can write JSON to the `attribute` field, or store each attribute in a separate table with a product ID. See Chapter 6 for more information about implementing these types of database models.

You can apply the preceding questions to the other information you'll need to store as well. For keeping track of the prices found for each product, you'll likely need the following:

- Product ID
- Store ID
- Price
- Date/Timestamp price was found at

But what if you have a situation in which the product's attributes actually modify the price of the product? For instance, stores might charge more for a large shirt than a small one, because the large shirt requires more labor or materials. In this case, you may consider splitting the single shirt product into separate product listings for each size (so that each shirt product can be priced independently) or creating a new item type to store information about instances of a product, containing these fields:

- Product ID
- Instance type (the size of the shirt, in this case)

And each price would then look like this:

- Product Instance ID
- Store ID
- Price
- Date/Timestamp price was found at

While the subject of "products and prices" may seem overly specific, the basic questions you need to ask yourself, and the logic used when designing your Python objects, apply in almost every situation.

If you're scraping news articles, you may want basic information such as the following:

- Title
- Author
- Date
- Content

But say some articles contain a "revision date," or "related articles, or a "number of social media shares." Do you need these? Are they relevant to your project? How do you efficiently and flexibly store the number of social media shares when not all news sites use all forms of social media, and social media sites may grow or wane in popularity over time?

It can be tempting, when faced with a new project, to dive in and start writing Python to scrape websites immediately. The data model, left as an afterthought, often becomes strongly influenced by the availability and format of the data on the first website you scrape.

However, the data model is the underlying foundation of all the code that uses it. A poor decision in your model can easily lead to problems writing and maintaining code down the line, or difficulty in extracting and efficiently using the resulting data. Especially when dealing with a variety of websites—both known and unknown—it becomes vital to give serious thought and planning to what, exactly, you need to collect and how you need to store it.

Dealing with Different Website Layouts

One of the most impressive feats of a search engine such as Google is that it manages to extract relevant and useful data from a variety of websites, having no upfront knowledge about the website structure itself. Although we, as humans, are able to

immediately identify the title and main content of a page (barring instances of extremely poor web design), it is far more difficult to get a bot to do the same thing.

Fortunately, in most cases of web crawling, you're not looking to collect data from sites you've never seen before, but from a few, or a few dozen, websites that are pre-selected by a human. This means that you don't need to use complicated algorithms or machine learning to detect which text on the page "looks most like a title" or which is probably the "main content." You can determine what these elements are manually.

The most obvious approach is to write a separate web crawler or page parser for each website. Each might take in a URL, string, or `BeautifulSoup` object, and return a Python object for the thing that was scraped.

The following is an example of a `Content` class (representing a piece of content on a website, such as a news article) and two scraper functions that take in a `BeautifulSoup` object and return an instance of `Content`:

```
import requests

class Content:
    def __init__(self, url, title, body):
        self.url = url
        self.title = title
        self.body = body

def getPage(url):
    req = requests.get(url)
    return BeautifulSoup(req.text, 'html.parser')

def scrapeNYTimes(url):
    bs = getPage(url)
    title = bs.find("h1").text
    lines = bs.find_all("p", {"class":"story-content"})
    body = '\n'.join([line.text for line in lines])
    return Content(url, title, body)

def scrapeBrookings(url):
    bs = getPage(url)
    title = bs.find("h1").text
    body = bs.find("div",{"class","post-body"}).text
    return Content(url, title, body)

url = 'https://www.brookings.edu/blog/future-development'
    '/2018/01/26/delivering-inclusive-urban-access-3-unc'
    'omfortable-truths/'
content = scrapeBrookings(url)
print('Title: {}'.format(content.title))
print('URL: {}\n'.format(content.url))
print(content.body)

url = 'https://www.nytimes.com/2018/01/25/opinion/sunday/'
```

```
    'silicon-valley-immortality.html"
content = scrapeNYTimes(url)
print('Title: {}'.format(content.title))
print('URL: {}\n'.format(content.url))
print(content.body)
```

As you start to add scraper functions for additional news sites, you might notice a pattern forming. Every site's parsing function does essentially the same thing:

- Selects the title element and extracts the text for the title
- Selects the main content of the article
- Selects other content items as needed
- Returns a `Content` object instantiated with the strings found previously

The only real site-dependent variables here are the CSS selectors used to obtain each piece of information. BeautifulSoup's `find` and `find_all` functions take in two arguments—a tag string and a dictionary of key/value attributes—so you can pass these arguments in as parameters that define the structure of the site itself and the location of the target data.

To make things even more convenient, rather than dealing with all of these tag arguments and key/value pairs, you can use the BeautifulSoup `select` function with a single string CSS selector for each piece of information you want to collect and put all of these selectors in a dictionary object:

```
class Content:
    """
    Common base class for all articles/pages
    """

    def __init__(self, url, title, body):
        self.url = url
        self.title = title
        self.body = body

    def print(self):
        """
        Flexible printing function controls output
        """
        print("URL: {}".format(self.url))
        print("TITLE: {}".format(self.title))
        print("BODY:\n{}".format(self.body))


class Website:
    """
    Contains information about website structure
    """
```

```
    def __init__(self, name, url, titleTag, bodyTag):
        self.name = name
        self.url = url
        self.titleTag = titleTag
        self.bodyTag = bodyTag
```

Note that the `Website` class does not store information collected from the individual pages themselves, but stores instructions about *how* to collect that data. It doesn't store the title "My Page Title." It simply stores the string tag `h1` that indicates where the titles can be found. This is why the class is called `Website` (the information here pertains to the entire website) and not `Content` (which contains information from just a single page).

Using these `Content` and `Website` classes you can then write a `Crawler` to scrape the title and content of any URL that is provided for a given web page from a given website:

```
import requests
from bs4 import BeautifulSoup

class Crawler:

    def getPage(self, url):
        try:
            req = requests.get(url)
        except requests.exceptions.RequestException:
            return None
        return BeautifulSoup(req.text, 'html.parser')

    def safeGet(self, pageObj, selector):
        """
        Utility function used to get a content string from a
        Beautiful Soup object and a selector. Returns an empty
        string if no object is found for the given selector
        """
        selectedElems = pageObj.select(selector)
        if selectedElems is not None and len(selectedElems) > 0:
            return '\n'.join(
            [elem.get_text() for elem in selectedElems])
        return ''

    def parse(self, site, url):
        """
        Extract content from a given page URL
        """
        bs = self.getPage(url)
        if bs is not None:
            title = self.safeGet(bs, site.titleTag)
            body = self.safeGet(bs, site.bodyTag)
            if title != '' and body != '':
```

```
                content = Content(url, title, body)
                content.print()
```

And here's the code that defines the website objects and kicks off the process:

```
crawler = Crawler()

siteData = [
    ['O\'Reilly Media', 'http://oreilly.com',
    'h1', 'section#product-description'],
    ['Reuters', 'http://reuters.com', 'h1',
    'div.StandardArticleBody_body_1gnLA'],
    ['Brookings', 'http://www.brookings.edu',
    'h1', 'div.post-body'],
    ['New York Times', 'http://nytimes.com',
    'h1', 'p.story-content']
]
websites = []
for row in siteData:
    websites.append(Website(row[0], row[1], row[2], row[3]))

crawler.parse(websites[0], 'http://shop.oreilly.com/product/'\
    '0636920028154.do')
crawler.parse(websites[1], 'http://www.reuters.com/article/'\
    'us-usa-epa-pruitt-idUSKBN19W2D0')
crawler.parse(websites[2], 'https://www.brookings.edu/blog/'\
    'techtank/2016/03/01/idea-to-retire-old-methods-of-policy-education/')
crawler.parse(websites[3], 'https://www.nytimes.com/2018/01/'\
    '28/business/energy-environment/oil-boom.html')
```

While this new method might not seem remarkably simpler than writing a new Python function for each new website at first glance, imagine what happens when you go from a system with 4 website sources to a system with 20 or 200 sources.

Each list of strings is relatively easy to write. It doesn't take up much space. It can be loaded from a database or a CSV file. It can be imported from a remote source or handed off to an nonprogrammer with some frontend experience to fill out and add new websites to, and they never have to look at a line of code.

Of course, the downside is that you are giving up a certain amount of flexibility. In the first example, each website gets its own free-form function to select and parse HTML however necessary, in order to get the end result. In the second example, each website needs to have a certain structure in which fields are guaranteed to exist, data must be clean coming out of the field, and each target field must have a unique and reliable CSS selector.

However, I believe that the power and relative flexibility of this approach more than makes up for its real or perceived shortcomings. The next section covers specific applications and expansions of this basic template so that you can, for example, deal

with missing fields, collect different types of data, crawl only through specific parts of a website, and store more-complex information about pages.

Structuring Crawlers

Creating flexible and modifiable website layout types doesn't do much good if you still have to locate each link you want to scrape by hand. The previous chapter showed various methods of crawling through websites and finding new pages in an automated way.

This section shows how to incorporate these methods into a well-structured and expandable website crawler that can gather links and discover data in an automated way. I present just three basic web crawler structures here, although I believe that they apply to the majority of situations that you will likely need when crawling sites in the wild, perhaps with a few modifications here and there. If you encounter an unusual situation with your own crawling problem, I also hope that you will use these structures as inspiration in order to create an elegant and robust crawler design.

Crawling Sites Through Search

One of the easiest ways to crawl a website is via the same method that humans do: using the search bar. Although the process of searching a website for a keyword or topic and collecting a list of search results may seem like a task with a lot of variability from site to site, several key points make this surprisingly trivial:

- Most sites retrieve a list of search results for a particular topic by passing that topic as a string through a parameter in the URL. For example: `http://example.com?search=myTopic`. The first part of this URL can be saved as a property of the `Website` object, and the topic can simply be appended to it.
- After searching, most sites present the resulting pages as an easily identifiable list of links, usually with a convenient surrounding tag such as `<span class="result">`, the exact format of which can also be stored as a property of the `Website` object.
- Each *result link* is either a relative URL (e.g., */articles/page.html*) or an absolute URL (e.g., *http://example.com/articles/page.html*). Whether or not you are expecting an absolute or relative URL can be stored as a property of the `Website` object.
- After you've located and normalized the URLs on the search page, you've successfully reduced the problem to the example in the previous section—extracting data from a page, given a website format.

Let's look at an implementation of this algorithm in code. The `Content` class is much the same as in previous examples. You are adding the URL property to keep track of where the content was found:

```
class Content:
    """Common base class for all articles/pages"""

    def __init__(self, topic, url, title, body):
        self.topic = topic
        self.title = title
        self.body = body
        self.url = url

    def print(self):
        """
        Flexible printing function controls output
        """
        print("New article found for topic: {}".format(self.topic))
        print("TITLE: {}".format(self.title))
        print("BODY:\n{}".format(self.body))
        print("URL: {}".format(self.url))
```

The `Website` class has a few new properties added to it. The `searchUrl` defines where you should go to get search results if you append the topic you are looking for. The `resultListing` defines the "box" that holds information about each result, and the `resultUrl` defines the tag inside this box that will give you the exact URL for the result. The `absoluteUrl` property is a boolean that tells you whether these search results are absolute or relative URLs.

```
class Website:
    """Contains information about website structure"""

    def __init__(self, name, url, searchUrl, resultListing,
        resultUrl, absoluteUrl, titleTag, bodyTag):
        self.name = name
        self.url = url
        self.searchUrl = searchUrl
        self.resultListing = resultListing
        self.resultUrl = resultUrl
        self.absoluteUrl=absoluteUrl
        self.titleTag = titleTag
        self.bodyTag = bodyTag
```

crawler.py has been expanded a bit and contains our `Website` data, a list of topics to search for, and a two loops that iterate through all the topics and all the websites. It also contains a `search` function that navigates to the search page for a particular website and topic, and extracts all the result URLs listed on that page.

```
import requests
from bs4 import BeautifulSoup
```

```
class Crawler:

    def getPage(self, url):
        try:
            req = requests.get(url)
        except requests.exceptions.RequestException:
            return None
        return BeautifulSoup(req.text, 'html.parser')

    def safeGet(self, pageObj, selector):
        childObj = pageObj.select(selector)
        if childObj is not None and len(childObj) > 0:
            return childObj[0].get_text()
        return ""

    def search(self, topic, site):
        """
        Searches a given website for a given topic and records all pages found
        """
        bs = self.getPage(site.searchUrl + topic)
        searchResults = bs.select(site.resultListing)
        for result in searchResults:
            url = result.select(site.resultUrl)[0].attrs["href"]
            # Check to see whether it's a relative or an absolute URL
            if(site.absoluteUrl):
                bs = self.getPage(url)
            else:
                bs = self.getPage(site.url + url)
            if bs is None:
                print("Something was wrong with that page or URL. Skipping!")
                return
            title = self.safeGet(bs, site.titleTag)
            body = self.safeGet(bs, site.bodyTag)
            if title != '' and body != '':
                content = Content(topic, title, body, url)
                content.print()


crawler = Crawler()

siteData = [
    ['O\'Reilly Media', 'http://oreilly.com',
        'https://ssearch.oreilly.com/?q=','article.product-result',
        'p.title a', True, 'h1', 'section#product-description'],
    ['Reuters', 'http://reuters.com',
        'http://www.reuters.com/search/news?blob=',
        'div.search-result-content','h3.search-result-title a',
        False, 'h1', 'div.StandardArticleBody_body_1gnLA'],
    ['Brookings', 'http://www.brookings.edu',
        'https://www.brookings.edu/search/?s=',
        'div.list-content article', 'h4.title a', True, 'h1',
```

```
            'div.post-body']
    ]
    sites = []
    for row in siteData:
        sites.append(Website(row[0], row[1], row[2],
                             row[3], row[4], row[5], row[6], row[7]))

    topics = ['python', 'data science']
    for topic in topics:
        print("GETTING INFO ABOUT: " + topic)
        for targetSite in sites:
            crawler.search(topic, targetSite)
```

This script loops through all the topics in the `topics` list and announces before it starts scraping for a topic:

```
GETTING INFO ABOUT python
```

Then it loops through all of the sites in the `sites` list and crawls each particular site for each particular topic. Each time that it successfully scrapes information about a page, it prints it to the console:

```
New article found for topic: python
URL: http://example.com/examplepage.html
TITLE: Page Title Here
BODY: Body content is here
```

Note that it loops through all topics and then loops through all websites in the inner loop. Why not do it the other way around, collecting all topics from one website, and then all topics from the next website? Looping through all topics first is a way to more evenly distribute the load placed on any one web server. This is especially important if you have a list of hundreds of topics and dozens of websites. You're not making tens of thousands of requests to one website at once; you're making 10 requests, waiting a few minutes, making another 10 requests, waiting a few minutes, and so forth.

Although the number of requests is ultimately the same either way, it's generally better to distribute these requests over time as much as is reasonable. Paying attention to how your loops are structured is an easy way to do this.

Crawling Sites Through Links

The previous chapter covered some ways of identifying internal and external links on web pages and then using those links to crawl across the site. In this section, you'll combine those same basic methods into a more flexible website crawler that can follow any link matching a specific URL pattern.

This type of crawler works well for projects when you want to gather all the data from a site—not just data from a specific search result or page listing. It also works well when the site's pages may be disorganized or widely dispersed.

These types of crawlers don't require a structured method of locating links, as in the previous section on crawling through search pages, so the attributes that describe the search page aren't required in the `Website` object. However, because the crawler isn't given specific instructions for the locations/positions of the links it's looking for, you do need some rules to tell it what sorts of pages to select. You provide a `targetPattern` (regular expression for the target URLs) and leave the boolean `absoluteUrl` variable to accomplish this:

```
class Website:
    def __init__(self, name, url, targetPattern, absoluteUrl,
        titleTag, bodyTag):
        self.name = name
        self.url = url
        self.targetPattern = targetPattern
        self.absoluteUrl=absoluteUrl
        self.titleTag = titleTag
        self.bodyTag = bodyTag

class Content:
    def __init__(self, url, title, body):
        self.url = url
        self.title = title
        self.body = body

    def print(self):
        print("URL: {}".format(self.url))
        print("TITLE: {}".format(self.title))
        print("BODY:\n{}".format(self.body))
```

The `Content` class is the same one used in the first crawler example.

The `Crawler` class is written to start from the home page of each site, locate internal links, and parse the content from each internal link found:

```
import re

class Crawler:
    def __init__(self, site):
        self.site = site
        self.visited = []

    def getPage(self, url):
        try:
            req = requests.get(url)
        except requests.exceptions.RequestException:
            return None
        return BeautifulSoup(req.text, 'html.parser')
```

```
    def safeGet(self, pageObj, selector):
        selectedElems = pageObj.select(selector)
        if selectedElems is not None and len(selectedElems) > 0:
            return '\n'.join([elem.get_text() for
                elem in selectedElems])
        return ''

    def parse(self, url):
        bs = self.getPage(url)
        if bs is not None:
            title = self.safeGet(bs, self.site.titleTag)
            body = self.safeGet(bs, self.site.bodyTag)
            if title != '' and body != '':
                content = Content(url, title, body)
                content.print()

    def crawl(self):
        """
        Get pages from website home page
        """
        bs = self.getPage(self.site.url)
        targetPages = bs.findAll('a',
            href=re.compile(self.site.targetPattern))
        for targetPage in targetPages:
            targetPage = targetPage.attrs['href']
            if targetPage not in self.visited:
                self.visited.append(targetPage)
                if not self.site.absoluteUrl:
                    targetPage = '{}{}'.format(self.site.url, targetPage)
                self.parse(targetPage)

reuters = Website('Reuters', 'https://www.reuters.com', '^(/article/)', False,
    'h1', 'div.StandardArticleBody_body_1gnLA')
crawler = Crawler(reuters)
crawler.crawl()
```

Another change here that was not used in previous examples: the `Website` object (in this case, the variable `reuters`) is a property of the `Crawler` object itself. This works well to store the visited pages (`visited`) in the crawler, but means that a new crawler must be instantiated for each website rather than reusing the same one to crawl a list of websites.

Whether you choose to make a crawler website-agnostic or choose to make the website an attribute of the crawler is a design decision that you must weigh in the context of your own specific needs. Either approach is generally fine.

Another thing to note is that this crawler will get the pages from the home page, but will not continue crawling after all those pages have been logged. You may want to write a crawler incorporating one of the patterns in Chapter 3 and have it look for more targets on each page it visits. You can even follow all the URLs on each page

(not just ones matching the target pattern) to look for URLs containing the target pattern.

Crawling Multiple Page Types

Unlike crawling through a predetermined set of pages, crawling through all internal links on a website can present a challenge in that you never know exactly what you're getting. Fortunately, there are a few basic ways to identify the page type:

By the URL
: All blog posts on a website might contain a URL (*http://example.com/blog/title-of-post*, for example).

By the presence or lack of certain fields on a site
: If a page has a date, but no author name, you might categorize it as a press release. If it has a title, main image, price, but no main content, it might be a product page.

By the presence of certain tags on the page to identify the page
: You can take advantage of tags even if you're not collecting the data within the tags. Your crawler might look for an element such as `<div id="related-products">` to identify the page as a product page, even though the crawler is not interested in the content of the related products.

To keep track of multiple page types, you need to have multiple types of page objects in Python. This can be done in two ways:

If the pages are all similar (they all have basically the same types of content), you may want to add a `pageType` attribute to your existing web-page object:

```
class Website:
    """Common base class for all articles/pages"""

    def __init__(self, type, name, url, searchUrl, resultListing,
        resultUrl, absoluteUrl, titleTag, bodyTag):
        self.name = name
        self.url = url
        self.titleTag = titleTag
        self.bodyTag = bodyTag
        self.pageType = pageType
```

If you're storing these pages in an SQL-like database, this type of pattern indicates that all these pages would probably be stored in the same table, and that an extra `pageType` column would be added.

If the pages/content you're scraping are different enough from each other (they contain different types of fields), this may warrant creating new objects for each page type. Of course, some things will be common to all web pages—they will all have a

URL, and will likely also have a name or page title. This is an ideal situation in which to use subclasses:

```
class Webpage:
    """Common base class for all articles/pages"""

    def __init__(self, name, url, titleTag):
        self.name = name
        self.url = url
        self.titleTag = titleTag
```

This is not an object that will be used directly by your crawler, but an object that will be referenced by your page types:

```
class Product(Website):
    """Contains information for scraping a product page"""
    def __init__(self, name, url, titleTag, productNumber, price):
        Website.__init__(self, name, url, TitleTag)
        self.productNumberTag = productNumberTag
        self.priceTag = priceTag

class Article(Website):
    """Contains information for scraping an article page"""
    def __init__(self, name, url, titleTag, bodyTag, dateTag):
        Website.__init__(self, name, url, titleTag)
        self.bodyTag = bodyTag
        self.dateTag = dateTag
```

This Product page extends the `Website` base class and adds the attributes `productNumber` and `price` that apply only to products, and the `Article` class adds the attributes `body` and `date`, which don't apply to products.

You can use these two classes to scrape, for example, a store website that might contain blog posts or press releases in addition to products.

Thinking About Web Crawler Models

Collecting information from the internet can be like drinking from a fire hose. There's a lot of stuff out there, and it's not always clear what you need or how you need it. The first step of any large web scraping project (and even some of the small ones) should be to answer these questions.

When collecting similar data across multiple domains or from multiple sources, your goal should almost always be to try to normalize it. Dealing with data with identical and comparable fields is much easier than dealing with data that is completely dependent on the format of its original source.

In many cases, you should build scrapers under the assumption that more sources of data will be added to them in the future, and with the goal to minimize the programming overhead required to add these new sources. Even if a website doesn't appear to

fit your model at first glance, there may be more subtle ways that it does conform. Being able to see these underlying patterns can save you time, money, and a lot of headaches in the long run.

The connections between pieces of data should also not be ignored. Are you looking for information that has properties such as "type," "size," or "topic" that span across data sources? How do you store, retrieve, and conceptualize these attributes?

Software architecture is a broad and important topic that can take an entire career to master. Fortunately, software architecture for web scraping is a much more finite and manageable set of skills that can be relatively easily acquired. As you continue to scrape data, you will likely find the same basic patterns occurring over and over. Creating a well-structured web scraper doesn't require a lot of arcane knowledge, but it does require taking a moment to step back and think about your project.

CHAPTER 5

Scrapy

The previous chapter presented some techniques and patterns for building large, scalable, and (most important!) maintainable web crawlers. Although this is easy enough to do by hand, many libraries, frameworks, and even GUI-based tools will do this for you, or at least try to make your life a little easier.

This chapter introduces one of the best frameworks for developing crawlers: Scrapy. During the writing of the first edition of *Web Scraping with Python*, Scrapy had not yet been released for Python 3.x, and its inclusion in the text was limited to a single section. Since then, the library has been updated to support Python 3.3+, additional features have been added, and I'm excited to expand this section into its own chapter.

One of the challenges of writing web crawlers is that you're often performing the same tasks again and again: find all links on a page, evaluate the difference between internal and external links, go to new pages. These basic patterns are useful to know and to be able to write from scratch, but the Scrapy library handles many of these details for you.

Of course, Scrapy isn't a mind reader. You still need to define page templates, give it locations to start scraping from, and define URL patterns for the pages that you're looking for. But in these cases, it provides a clean framework to keep your code organized.

Installing Scrapy

Scrapy offers the tool for download from its website, as well as instructions for installing Scrapy with third-party installation managers such as pip.

Because of its relatively large size and complexity, Scrapy is not usually a framework that can be installed in the traditional way with

```
$ pip install Scrapy
```

Note that I say "usually" because, though it is theoretically possible, I usually run into one or more tricky dependency issues, version mismatches, and unsolvable bugs.

If you're determined to install Scrapy from pip, using a virtual environment (see the "Keeping Libraries Straight with Virtual Environments" on page 7 for more on virtual environments) is highly recommended.

The installation method that I prefer is through the Anaconda package manager. Anaconda is a product, produced by the company Continuum, designed to reduce friction when it comes to finding and installing popular Python data science packages. Many of the packages it manages, such as NumPy and NLTK, will be used in later chapters as well.

After Anaconda is installed, you can install Scrapy by using this command:

```
conda install -c conda-forge scrapy
```

If you run into issues, or need up-to-date information, check out the Scrapy Installation guide for more information.

Initializing a New Spider

Once you've installed the Scrapy framework, a small amount of setup needs to be done for each spider. A *spider* is a Scrapy project that, like its arachnid namesake, is designed to crawl webs. Throughout this chapter, I use "spider" to describe a Scrapy project in particular, and "crawler" to mean "any generic program that crawls the web, using Scrapy or not."

To create a new spider in the current directory, run the following from the command line:

```
$ scrapy startproject wikiSpider
```

This creates a new subdirectory in the directory the project was created in, with the title *wikiSpider*. Inside this directory is the following file structure:

- *scrapy.cfg*
- *wikiSpider*
  - — *spiders*
    - — *__init.py__*
  - — *items.py*
  - — *middlewares.py*
  - — *pipelines.py*
  - — *settings.py*

— __init.py__

These Python files are initialized with stub code to provide a fast means of creating a new spider project. Each section in this chapter works with this *wikiSpider* project.

Writing a Simple Scraper

To create a crawler, you will add a new file inside the *spiders* directory at *wikiSpider/wikiSpider/spiders/article.py*. In your newly created *article.py* file, write the following:

```
import scrapy
      class name
class ArticleSpider(scrapy.Spider):
    name='article'

    def start_requests(self):
        urls = [
            'http://en.wikipedia.org/wiki/Python_'
            '%28programming_language%29',
            'https://en.wikipedia.org/wiki/Functional_programming',
            'https://en.wikipedia.org/wiki/Monty_Python']
        return [scrapy.Request(url=url, callback=self.parse)
            for url in urls]

    def parse(self, response):
        url = response.url
        title = response.css('h1::text').extract_first()
        print('URL is: {}'.format(url))
        print('Title is: {}'.format(title))
```

The name of this class (`ArticleSpider`) is different from the name of the directory (*wikiSpider*), indicating that this class in particular is responsible for spidering through only article pages, under the broader category of *wikiSpider*, which you may later want to use to search for other page types.

For large sites with many types of content, you might have separate Scrapy items for each type (blog posts, press releases, articles, etc.), each with different fields, but all running under the same Scrapy project. The name of each spider must be unique within the project.

The other key things to notice about this spider are the two functions `start_requests` and `parse`.

`start_requests` is a Scrapy-defined entry point to the program used to generate `Request` objects that Scrapy uses to crawl the website.

`parse` is a callback function defined by the user, and is passed to the `Request` object with `callback=self.parse`. Later, you'll look at more-powerful things that can be done with the `parse` function, but for now it prints the title of the page.

You can run this `article` spider by navigating to the *wikiSpider/wikiSpider* directory and running:

```
$ scrapy runspider article.py
```

The default Scrapy output is fairly verbose. Along with debugging information, this should print out lines like the following:

```
2018-01-21 23:28:57 [scrapy.core.engine] DEBUG: Crawled (200)
<GET https://en.wikipedia.org/robots.txt> (referer: None)
2018-01-21 23:28:57 [scrapy.downloadermiddlewares.redirect]
DEBUG: Redirecting (301) to <GET https://en.wikipedia.org/wiki/
Python_%28programming_language%29> from <GET http://en.wikipedia.org/
wiki/Python_%28programming_language%29>
2018-01-21 23:28:57 [scrapy.core.engine] DEBUG: Crawled (200)
<GET https://en.wikipedia.org/wiki/Functional_programming>
(referer: None)
URL is: https://en.wikipedia.org/wiki/Functional_programming
Title is: Functional programming
2018-01-21 23:28:57 [scrapy.core.engine] DEBUG: Crawled (200)
<GET https://en.wikipedia.org/wiki/Monty_Python> (referer: None)
URL is: https://en.wikipedia.org/wiki/Monty_Python
Title is: Monty Python
```

The scraper goes to the three pages listed as the `start_urls`, gathers information, and then terminates.

Spidering with Rules

The spider in the previous section isn't much of a crawler, confined to scraping only the list of URLs it's provided. It has no ability to seek new pages on its own. To turn it into a fully fledged crawler, you need to use the `CrawlSpider` class provided by Scrapy.

Code Organization Within the GitHub Repository

Unfortunately, the Scrapy framework cannot be easily run from within a Jupyter notebook, making a linear progression of code difficult to capture. For the purpose of presenting all code samples in the text, the scraper from the previous section is stored in the *article.py* file, while the following example, creating a Scrapy spider that traverses many pages, is stored in *articles.py* (note the use of the plural).

Later examples will also be stored in separate files, with new filenames given in each section. Make sure you are using the correct filename when running these examples.

This class can be found in *articles.py* in the Github repository:

```
from scrapy.contrib.linkextractors import LinkExtractor
from scrapy.contrib.spiders import CrawlSpider, Rule

class ArticleSpider(CrawlSpider):
    name = 'articles'
    allowed_domains = ['wikipedia.org']
    start_urls = ['https://en.wikipedia.org/wiki/'
        'Benevolent_dictator_for_life']
    rules = [Rule(LinkExtractor(allow=r'.*'), callback='parse_items',
        follow=True)]

    def parse_items(self, response):
        url = response.url
        title = response.css('h1::text').extract_first()
        text = response.xpath('//div[@id="mw-content-text"]//text()')
            .extract()
        lastUpdated = response.css('li#footer-info-lastmod::text')
            .extract_first()
        lastUpdated = lastUpdated.replace(
            'This page was last edited on ', '')
        print('URL is: {}'.format(url))
        print('title is: {} '.format(title))
        print('text is: {}'.format(text))
        print('Last updated: {}'.format(lastUpdated))
```

This new `ArticleSpider` extends the `CrawlSpider` class. Rather than providing a `start_requests` function, it provides a list of `start_urls` and `allowed_domains`. This tells the spider where to start crawling from and whether it should follow or ignore a link based on the domain.

A list of `rules` is also provided. This provides further instructions on which links to follow or ignore (in this case, you are allowing all URLs with the regular expression `.*`).

In addition to extracting the title and URL on each page, a couple of new items have been added. The text content of each page is extracted using an XPath selector. XPath is often used when retrieving text content including text in child tags (for example, an `<a>` tag inside a block of text). If you use the CSS selector to do this, all text within child tags will be ignored.

The last updated date string is also parsed from the page footer and stored in the `lastUpdated` variable.

You can run this example by navigating to the *wikiSpider/wikiSpider* directory and running this:

```
$ scrapy runspider articles.py
```

Warning: This Will Run Forever

This spider will run from the command line in the same way as the previous one, but it will not terminate (at least not for a very, very long time) until you halt execution by using Ctrl-C or by closing the terminal. Please be kind to Wikipedia's server load and do not run it for long.

When run, this spider traverses *wikipedia.org*, following all links under the domain *wikipedia.org*, printing titles of pages, and ignoring all external (offsite) links:

```
2018-01-21 01:30:36 [scrapy.spidermiddlewares.offsite]
DEBUG: Filtered offsite request to 'www.chicagomag.com':
<GET http://www.chicagomag.com/Chicago-Magazine/June-2009/
Street-Wise/>
2018-01-21 01:30:36 [scrapy.downloadermiddlewares.robotstxt]
DEBUG: Forbidden by robots.txt: <GET https://en.wikipedia.org/w/
index.php?title=Adrian_Holovaty&action=edit&section=3>
title is: Ruby on Rails
URL is: https://en.wikipedia.org/wiki/Ruby_on_Rails
text is: ['Not to be confused with ', 'Ruby (programming language)',
 '.', '\n', '\n', 'Ruby on Rails', ... ]
Last updated:  9 January 2018, at 10:32.
```

This is a pretty good crawler so far, but it could use a few limits. Instead of just visiting article pages on Wikipedia, it's free to roam to nonarticle pages as well, such as:

```
title is: Wikipedia:General disclaimer
```

Let's take a closer look at the line by using Scrapy's `Rule` and `LinkExtractor`:

```
rules = [Rule(LinkExtractor(allow=r'.*'), callback='parse_items',
    follow=True)]
```

This line provides a list of Scrapy `Rule` objects that define the rules that all links found are filtered through. When multiple rules are in place, each link is checked against the rules in order. The first rule that matches is the one that is used to determine how the link is handled. If the link doesn't match any rules, it is ignored.

A `Rule` can be provided with six arguments:

`link_extractor`
: The only mandatory argument, a `LinkExtractor` object.

`callback`
: The function that should be used to parse the content on the page.

`cb_kwargs`
: A dictionary of arguments to be passed to the callback function. This dictionary is formatted as `{arg_name1: arg_value1, arg_name2: arg_value2}` and can be a handy tool for reusing the same parsing functions for slightly different tasks.

`follow`
: Indicates whether you want links found at that page to be included in a future crawl. If no callback function is provided, this defaults to `True` (after all, if you're not doing anything with the page, it makes sense that you'd at least want to use it to continue crawling through the site). If a callback function is provided, this defaults to `False`.

`LinkExtractor` is a simple class designed solely to recognize and return links in a page of HTML content based on the rules provided to it. It has a number of arguments that can be used to accept or deny a link based on CSS and XPath selectors, tags (you can look for links in more than just anchor tags!), domains, and more.

The `LinkExtractor` class can even be extended, and custom arguments can be created. See Scrapy's documentation on link extractors for more information.

Despite all the flexible features of the `LinkExtractor` class, the most common arguments you'll probably use are these:

`allow`
: Allow all links that match the provided regular expression.

`deny`
: Deny all links that match the provided regular expression.

Using two separate `Rule` and `LinkExtractor` classes with a single parsing function, you can create a spider that crawls Wikipedia, identifying all article pages and flagging nonarticle pages (*articlesMoreRules.py*):

```
from scrapy.contrib.linkextractors import LinkExtractor
from scrapy.contrib.spiders import CrawlSpider, Rule

class ArticleSpider(CrawlSpider):
    name = 'articles'
    allowed_domains = ['wikipedia.org']
    start_urls = ['https://en.wikipedia.org/wiki/'
        'Benevolent_dictator_for_life']
    rules = [
        Rule(LinkExtractor(allow='^(/wiki/)((?!:).)*$'),
            callback='parse_items', follow=True,
            cb_kwargs={'is_article': True}),
        Rule(LinkExtractor(allow='.*'), callback='parse_items',
            cb_kwargs={'is_article': False})
    ]

    def parse_items(self, response, is_article):
        print(response.url)
        title = response.css('h1::text').extract_first()
        if is_article:
            url = response.url
            text = response.xpath('//div[@id="mw-content-text"]'
```

```
                '//text()').extract()
            lastUpdated = response.css('li#footer-info-lastmod'
                '::text').extract_first()
            lastUpdated = lastUpdated.replace('This page was '
                'last edited on ', '')
            print('Title is: {} '.format(title))
            print('title is: {} '.format(title))
            print('text is: {}'.format(text))
        else:
            print('This is not an article: {}'.format(title))
```

Recall that the rules are applied to each link in the order that they are presented in the list. All article pages (pages that start with */wiki/* and do not contain a colon) are passed to the `parse_items` function first with the default parameter `is_article=True`. Then all the other nonarticle links are passed to the `parse_items` function with the argument `is_article=False`.

Of course, if you're looking to collect only article-type pages and ignore all others, this approach would be impractical. It would be much easier to ignore pages that don't match the article URL pattern and leave out the second rule (and the `is_article` variable) altogether. However, this type of approach may be useful in odd cases where information from the URL, or information collected during crawling, impacts the way the page should be parsed.

Creating Items

So far, you've looked at many ways of finding, parsing, and crawling websites with Scrapy, but Scrapy also provides useful tools to keep your collected items organized and stored in custom objects with well-defined fields.

To help organize all the information you're collecting, you need to create an `Article` object. Define a new item called `Article` inside the *items.py* file.

When you open the *items.py* file, it should look like this:

```
# -*- coding: utf-8 -*-

# Define here the models for your scraped items
#
# See documentation in:
# http://doc.scrapy.org/en/latest/topics/items.html

import scrapy

class WikispiderItem(scrapy.Item):
    # define the fields for your item here like:
    # name = scrapy.Field()
    pass
```

Replace this default `Item` stub with a new `Article` class extending `scrapy.Item`:

```
import scrapy

class Article(scrapy.Item):
    url = scrapy.Field()
    title = scrapy.Field()
    text = scrapy.Field()
    lastUpdated = scrapy.Field()
```

You are defining three fields that will be collected from each page: a title, URL, and the date the page was last edited.

If you are collecting data for multiple page types, you should define each separate type as its own class in *items.py*. If your items are large, or you start to move more parsing functionality into your item objects, you may also wish to extract each item into its own file. While the items are small, however, I like to keep them in a single file.

In the file *articleSpider.py* note the the changes that were made to the `ArticleSpider` class in order to create the new `Article` item:

```
from scrapy.contrib.linkextractors import LinkExtractor
from scrapy.contrib.spiders import CrawlSpider, Rule
from wikiSpider.items import Article

class ArticleSpider(CrawlSpider):
    name = 'articleItems'
    allowed_domains = ['wikipedia.org']
    start_urls = ['https://en.wikipedia.org/wiki/Benevolent'
        '_dictator_for_life']
    rules = [
        Rule(LinkExtractor(allow='(/wiki/)((?!:).)*$'),
            callback='parse_items', follow=True),
    ]

    def parse_items(self, response):
        article = Article()
        article['url'] = response.url
        article['title'] = response.css('h1::text').extract_first()
        article['text'] = response.xpath('//div[@id='
            '"mw-content-text"]//text()').extract()
        lastUpdated = response.css('li#footer-info-lastmod::text')
            .extract_first()
        article['lastUpdated'] = lastUpdated.replace('This page was '
            'last edited on ', '')
        return article
```

When this file is run with

```
$ scrapy runspider articleItems.py
```

it will output the usual Scrapy debugging data along with each article item as a Python dictionary:

```
2018-01-21 22:52:38 [scrapy.spidermiddlewares.offsite] DEBUG:
Filtered offsite request to 'wikimediafoundation.org':
<GET https://wikimediafoundation.org/wiki/Terms_of_Use>
2018-01-21 22:52:38 [scrapy.core.engine] DEBUG: Crawled (200)
<GET https://en.wikipedia.org/wiki/Benevolent_dictator_for_life
#mw-head> (referer: https://en.wikipedia.org/wiki/Benevolent_
dictator_for_life)
2018-01-21 22:52:38 [scrapy.core.scraper] DEBUG: Scraped from
<200 https://en.wikipedia.org/wiki/Benevolent_dictator_for_life>
{'lastUpdated': ' 13 December 2017, at 09:26.',
'text': ['For the political term, see ',
          'Benevolent dictatorship',
          '.',
          ...
```

Using Scrapy `Items` isn't just for promoting good code organization or laying things out in a readable way. Items provide many tools for outputting and processing data, covered in the next sections.

Outputting Items

Scrapy uses the `Item` objects to determine which pieces of information it should save from the pages it visits. This information can be saved by Scrapy in a variety of ways, such as CSV, JSON, or XML files, using the following commands:

```
$ scrapy runspider articleItems.py -o articles.csv -t csv
$ scrapy runspider articleItems.py -o articles.json -t json
$ scrapy runspider articleItems.py -o articles.xml -t xml
```

Each of these runs the scraper `articleItems` and writes the output in the specified format to the provided file. This file will be created if it does not exist already.

You may have noticed that in the articles spider created in previous examples, the text variable is a list of strings rather than a single string. Each string in this list represents text inside a single HTML element, whereas the content inside `<div id="mw-content-text">`, from which you are collecting the text data, is composed of many child elements.

Scrapy manages these more complex values well. In the CSV format, for example, it converts lists to strings and escapes all commas so that a list of text displays in a single CSV cell.

In XML, each element of this list is preserved inside child value tags:

```
<items>
<item>
    <url>https://en.wikipedia.org/wiki/Benevolent_dictator_for_life</url>
```

```
        <title>Benevolent dictator for life</title>
        <text>
            <value>For the political term, see </value>
            <value>Benevolent dictatorship</value>
            ...
        </text>
        <lastUpdated> 13 December 2017, at 09:26.</lastUpdated>
    </item>
    ....
```

In the JSON format, lists are preserved as lists.

Of course, you can use the `Item` objects yourself and write them to a file or a database in whatever way you want, simply by adding the appropriate code to the parsing function in the crawler.

The Item Pipeline

Although Scrapy is single threaded, it is capable of making and handling many requests asynchronously. This makes it faster than the scrapers written so far in this book, although I have always been a firm believer that faster is not always better when it comes to web scraping.

The web server for the site you are trying to scrape must handle each of these requests, and it's important to be a good citizen and evaluate whether this sort of server hammering is appropriate (or even wise for your own self-interests, as many websites have the ability and the will to block what they might see as malicious scraping activity). For more information about the ethics of web scraping, as well as the importance of appropriately throttling scrapers, see Chapter 18.

With that said, using Scrapy's item pipeline can improve the speed of your web scraper even further by performing all data processing while waiting for requests to be returned, rather than waiting for data to be processed before making another request. This type of optimization can sometimes even be necessary when data processing requires a great deal of time or processor-heavy calculations must be performed.

To create an item pipeline, revisit the *settings.py* file that was created at the beginning of the chapter. You should see the following commented lines:

```
# Configure item pipelines
# See http://scrapy.readthedocs.org/en/latest/topics/item-pipeline.html
#ITEM_PIPELINES = {
#    'wikiSpider.pipelines.WikispiderPipeline': 300,
#}
```

Uncomment the last three lines and replace with the following:

```
ITEM_PIPELINES = {
    'wikiSpider.pipelines.WikispiderPipeline': 300,
}
```

This provides a Python class, `wikiSpider.pipelines.WikispiderPipeline`, that will be used to process the data, as well as an integer that represents the order in which to run the pipeline if there are multiple processing classes. Although any integer can be used here, the numbers 0–1000 are typically used, and will be run in ascending order.

Now you need to add the pipeline class and rewrite your original spider so that the spider collects data and the pipeline does the heavy lifting of the data processing. It might be tempting to write the `parse_items` method in your original spider to return the response and let the pipeline create the `Article` object:

```
def parse_items(self, response):
    return response
```

However, the Scrapy framework does not allow this, and an `Item` object (such as an `Article`, which extends `Item`) must be returned. So the goal of `parse_items` is now to extract the raw data, doing as little processing as possible, so that it can be passed to the pipeline:

```
from scrapy.contrib.linkextractors import LinkExtractor
from scrapy.contrib.spiders import CrawlSpider, Rule
from wikiSpider.items import Article

class ArticleSpider(CrawlSpider):
    name = 'articlePipelines'
    allowed_domains = ['wikipedia.org']
    start_urls = ['https://en.wikipedia.org/wiki/Benevolent_dictator_for_life']
    rules = [
        Rule(LinkExtractor(allow='(/wiki/)((?!:).)*$'),
            callback='parse_items', follow=True),
    ]

    def parse_items(self, response):
        article = Article()
        article['url'] = response.url
        article['title'] = response.css('h1::text').extract_first()
        article['text'] = response.xpath('//div[@id='
            '"mw-content-text"]//text()').extract()
        article['lastUpdated'] = response.css('li#'
            'footer-info-lastmod::text').extract_first()
        return article
```

This file is saved as *articlePipelines.py* in the GitHub repository.

Of course, now you need to tie the *settings.py* file and the updated spider together by adding the pipeline. When the Scrapy project was first initialized, a file was created at *wikiSpider/wikiSpider/settings.py*:

```
# -*- coding: utf-8 -*-

# Define your item pipelines here
#
```

```
# Don't forget to add your pipeline to the ITEM_PIPELINES setting
# See: http://doc.scrapy.org/en/latest/topics/item-pipeline.html


class WikispiderPipeline(object):
    def process_item(self, item, spider):
        return item
```

This stub class should be replaced with your new pipeline code. In previous sections, you've been collecting two fields in a raw format, and these could use additional processing: `lastUpdated` (which is a badly formatted string object representing a date) and `text` (a messy array of string fragments).

The following should be used to replace the stub code in *wikiSpider/wikiSpider/settings.py:*

```
from datetime import datetime
from wikiSpider.items import Article
from string import whitespace

class WikispiderPipeline(object):
    def process_item(self, article, spider):
        dateStr = article['lastUpdated']
        article['lastUpdated'] = article['lastUpdated']
            .replace('This page was last edited on', '')
        article['lastUpdated'] = article['lastUpdated'].strip()
        article['lastUpdated'] = datetime.strptime(
            article['lastUpdated'], '%d %B %Y, at %H:%M.')
        article['text'] = [line for line in article['text']
            if line not in whitespace]
        article['text'] = ''.join(article['text'])
        return article
```

The class `WikispiderPipeline` has a method `process_item` that takes in an `Article` object, parses the `lastUpdated` string into a Python `datetime` object, and cleans and joins the text into a single string from a list of strings.

`process_item` is a mandatory method for every pipeline class. Scrapy uses this method to asynchronously pass `Items` that are collected by the spider. The parsed `Article` object that is returned here will be logged or printed by Scrapy if, for example, you are outputting items to JSON or CSV as was done in the previous section.

You now have two choices when it comes to deciding where to do your data processing: the `parse_items` method in the spider, or the `process_items` method in the pipeline.

Multiple pipelines with different tasks can be declared in the *settings.py* file. However, Scrapy passes all items, regardless of item type, to each pipeline in order. Item-specific parsing may be better handled in the spider, before the data hits the pipeline. However, if this parsing takes a long time, you may want to consider moving it to the

pipeline (where it can be processed asynchronously) and adding a check on the item type:

```
def process_item(self, item, spider):
    if isinstance(item, Article):
        # Article-specific processing here
```

Which processing to do and where to do it is an important consideration when it comes to writing Scrapy projects, especially large ones.

Logging with Scrapy

The debug information generated by Scrapy can be useful, but, as you've likely noticed, it is often too verbose. You can easily adjust the level of logging by adding a line to the *settings.py* file in your Scrapy project:

```
LOG_LEVEL = 'ERROR'
```

Scrapy uses a standard hierarchy of logging levels, as follows:

- `CRITICAL`
- `ERROR`
- `WARNING`
- `DEBUG`
- `INFO`

If logging is set to `ERROR`, only `CRITICAL` and `ERROR` logs will be displayed. If logging is set to `INFO`, all logs will be displayed, and so on.

In addition to controlling logging through the *settings.py* file, you can control where the logs go from the command line. To output logs to a separate logfile instead of the terminal, define a logfile when running from the command line:

```
$ scrapy crawl articles -s LOG_FILE=wiki.log
```

This creates a new logfile, if one does not exist, in your current directory and outputs all logs to it, leaving your terminal clear to display only the Python print statements you manually add.

More Resources

Scrapy is a powerful tool that handles many problems associated with crawling the web. It automatically gathers all URLs and compares them against predefined rules, makes sure all URLs are unique, normalizes relative URLs where needed, and recurses to go more deeply into pages.

Although this chapter hardly scratches the surface of Scrapy's capabilities, I encourage you to check out the Scrapy documentation as well as *Learning Scrapy*, by Dimitrios Kouzis-Loukas (O'Reilly), which provides a comprehensive discourse on the framework.

Scrapy is an extremely large and sprawling library with many features. Its features work together seamlessly, but have many areas of overlap that allow users to easily develop their own particular style within it. If there's something you'd like to do with Scrapy that has not been mentioned here, there is likely a way (or several) to do it!

CHAPTER 6
Storing Data

Although printing to the terminal is a lot of fun, it's not incredibly useful when it comes to data aggregation and analysis. To make the majority of web scrapers remotely useful, you need to be able to save the information that they scrape.

This chapter covers three main methods of data management that are sufficient for almost any imaginable application. Do you need to power the backend of a website or create your own API? You'll probably want your scrapers to write to a database. Need a fast and easy way to collect documents off the internet and put them on your hard drive? You'll probably want to create a file stream for that. Need occasional alerts, or aggregated data once a day? Send yourself an email!

Above and beyond web scraping, the ability to store and interact with large amounts of data is incredibly important for just about any modern programming application. In fact, the information in this chapter is necessary for implementing many of the examples in later sections of the book. I highly recommend that you at least skim this chapter if you're unfamiliar with automated data storage.

Media Files

You can store media files in two main ways: by reference and by downloading the file itself. You can store a file by reference by storing the URL where the file is located. This has several advantages:

- Scrapers run much faster and require much less bandwidth when they don't have to download files.
- You save space on your own machine by storing only the URLs.
- It is easier to write code that stores only URLs and doesn't need to deal with additional file downloads.

- You can lessen the load on the host server by avoiding large file downloads.

Here are the disadvantages:

- Embedding these URLs in your own website or application is known as *hotlinking*, and doing it is a quick way to get you in hot water on the internet.
- You do not want to use someone else's server cycles to host media for your own applications.
- The file hosted at any particular URL is subject to change. This might lead to embarrassing effects if, say, you're embedding a hotlinked image on a public blog. If you're storing the URLs with the intent to store the file later, for further research, it might eventually go missing or be changed to something completely irrelevant at a later date.
- Real web browsers do not just request a page's HTML and move on. They download all of the assets required by the page as well. Downloading files can help make your scraper look like a human is browsing the site, which can be an advantage.

If you're debating over whether to store a file or a URL to a file, you should ask yourself whether you're likely to view or read that file more than once or twice, or if this database of files is going to be sitting around gathering electronic dust for most of its life. If the answer is the latter, it's probably best to simply store the URL. If it's the former, read on!

The `urllib` library, used to retrieve the content of webpages also contains functions to retrieve the content of files. The following program uses `urllib.request.urlretrieve` to download images from a remote URL:

```
from urllib.request import urlretrieve
from urllib.request import urlopen
from bs4 import BeautifulSoup

html = urlopen('http://www.pythonscraping.com')
bs = BeautifulSoup(html, 'html.parser')
imageLocation = bs.find('a', {'id': 'logo'}).find('img')['src']
urlretrieve (imageLocation, 'logo.jpg')
```

This downloads the logo from *http://pythonscraping.com* and stores it as *logo.jpg* in the same directory from which the script is running.

This works well if you need to download only a single file and know what to call it and what the file extension is. But most scrapers don't download a single file and call it a day. The following downloads all internal files, linked to by any tag's `src` attribute, from the home page of *http://pythonscraping.com*:

```python
import os
from urllib.request import urlretrieve
from urllib.request import urlopen
from bs4 import BeautifulSoup

downloadDirectory = 'downloaded'
baseUrl = 'http://pythonscraping.com'

def getAbsoluteURL(baseUrl, source):
    if source.startswith('http://www.'):
        url = 'http://{}'.format(source[11:])
    elif source.startswith('http://'):
        url = source
    elif source.startswith('www.'):
        url = source[4:]
        url = 'http://{}'.format(source)
    else:
        url = '{}/{}'.format(baseUrl, source)
    if baseUrl not in url:
        return None
    return url

def getDownloadPath(baseUrl, absoluteUrl, downloadDirectory):
    path = absoluteUrl.replace('www.', '')
    path = path.replace(baseUrl, '')
    path = downloadDirectory+path
    directory = os.path.dirname(path)

    if not os.path.exists(directory):
        os.makedirs(directory)

    return path

html = urlopen('http://www.pythonscraping.com')
bs = BeautifulSoup(html, 'html.parser')
downloadList = bs.findAll(src=True)

for download in downloadList:
    fileUrl = getAbsoluteURL(baseUrl, download['src'])
    if fileUrl is not None:
        print(fileUrl)

urlretrieve(fileUrl, getDownloadPath(baseUrl, fileUrl, downloadDirectory))
```

Run with Caution

You know all those warnings you hear about downloading unknown files off the internet? This script downloads everything it comes across to your computer's hard drive. This includes random bash scripts, *.exe* files, and other potential malware.

Think you're safe because you'd never actually execute anything sent to your downloads folder? Especially if you run this program as an administrator, you're asking for trouble. What happens if you run across a file on a website that sends itself to *../../../../usr/bin/python*? The next time you run a Python script from the command line, you could be deploying malware on your machine!

This program is written for illustrative purposes only; it should not be randomly deployed without more extensive filename checking, and it should be run only in an account with limited permissions. As always, backing up your files, not storing sensitive information on your hard drive, and using a little common sense go a long way.

This script uses a lambda function (introduced in Chapter 2) to select all tags on the front page that have the `src` attribute, and then cleans and normalizes the URLs to get an absolute path for each download (making sure to discard external links). Then, each file is downloaded to its own path in the local folder *downloaded* on your own machine.

Notice that Python's `os` module is used briefly to retrieve the target directory for each download and create missing directories along the path if needed. The `os` module acts as an interface between Python and the operating system, allowing it to manipulate file paths, create directories, get information about running processes and environment variables, and many other useful things.

Storing Data to CSV

CSV, or *comma-separated values*, is one of the most popular file formats in which to store spreadsheet data. It is supported by Microsoft Excel and many other applications because of its simplicity. The following is an example of a perfectly valid CSV file:

```
fruit,cost
apple,1.00
banana,0.30
pear,1.25
```

As with Python, whitespace is important here: each row is separated by a newline character, while columns within the row are separated by commas (hence the name "comma-separated"). Other forms of CSV files (sometimes called *character-separated*

value files) use tabs or other characters to separate rows, but these file formats are less common and less widely supported.

If you're looking to download CSV files directly off the web and store them locally, without any parsing or modification, you don't need this section. Download them like you would any other file, and save them with the CSV file format by using the methods described in the previous section.

Modifying a CSV file, or even creating one entirely from scratch, is extremely easy with Python's *csv* library:

```
import csv

csvFile = open('test.csv', 'w+')
try:
    writer = csv.writer(csvFile)
    writer.writerow(('number', 'number plus 2', 'number times 2'))
    for i in range(10):
        writer.writerow( (i, i+2, i*2))
finally:
    csvFile.close()
```

A precautionary reminder: file creation in Python is fairly bulletproof. If *test.csv* does not already exist, Python will create the file (but not the directory) automatically. If it already exists, Python will overwrite *test.csv* with the new data.

After running, you should see a CSV file:

```
number,number plus 2,number times 2
0,2,0
1,3,2
2,4,4
...
```

One common web scraping task is to retrieve an HTML table and write it as a CSV file. Wikipedia's Comparison of Text Editors provides a fairly complex HTML table, complete with color coding, links, sorting, and other HTML garbage that needs to be discarded before it can be written to CSV. Using BeautifulSoup and the `get_text()` function copiously, you can do that in fewer than 20 lines:

```
import csv
from urllib.request import urlopen
from bs4 import BeautifulSoup

html = urlopen('http://en.wikipedia.org/wiki/'
    'Comparison_of_text_editors')
bs = BeautifulSoup(html, 'html.parser')
#The main comparison table is currently the first table on the page
table = bs.findAll('table',{'class':'wikitable'})[0]
rows = table.findAll('tr')

csvFile = open('editors.csv', 'wt+')
```

```
writer = csv.writer(csvFile)
try:
    for row in rows:
        csvRow = []
        for cell in row.findAll(['td', 'th']):
            csvRow.append(cell.get_text())
            writer.writerow(csvRow)
finally:
    csvFile.close()
```

There Is an Easier Way to Fetch a Single Table

This script is great to integrate into scrapers if you encounter many HTML tables that need to be converted to CSV files, or many HTML tables that need to be collected into a single CSV file. However, if you only need to do it just once, there's a better tool for that: copying and pasting. Selecting and copying all the content of an HTML table and pasting it into Excel or Google Docs will get you the CSV file you're looking for without running a script!

The result should be a well-formatted CSV file saved locally, under *../files/editors.csv*.

MySQL

MySQL (officially pronounced "my es-kew-el," although many say, "my sequel") is the most popular open source relational database management system today. Somewhat unusually for an open source project with large competitors, its popularity has historically been neck and neck with the two other major closed source database systems: Microsoft's SQL Server and Oracle's DBMS.

Its popularity is not without cause. For most applications, it's hard to go wrong with MySQL. It's a scalable, robust, and full-featured DBMS, used by top websites: YouTube,[1] Twitter,[2] and Facebook,[3] among many others.

Because of its ubiquity, price ("free" is a pretty great price), and out-of-box usability, it makes a fantastic database for web scraping projects, and we will use it throughout the remainder of this book.

"Relational" Database?

Relational data is data that has relations. Glad we cleared that up!

1 Joab Jackson, "YouTube Scales MySQL with Go Code", PCWorld, December 15, 2012.

2 Jeremy Cole and Davi Arnaut, "MySQL at Twitter", The Twitter Engineering Blog, April 9, 2012.

3 "MySQL and Database Engineering: Mark Callaghan", Facebook Engineering, March 4, 2012.

Just kidding! When computer scientists talk about relational data, they're referring to data that doesn't exist in a vacuum—it has properties that relate it to other pieces of data. For example, "User A goes to school at Institution B," where User A can be found in the Users table in the database and Institution B can be found in the Institutions table in the database.

Later in this chapter, you'll take a look at modeling different types of relations and storing data in MySQL (or any other relational database) effectively.

Installing MySQL

If you're new to MySQL, installing a database might sound a little intimidating (if you're an old hat at it, feel free to skip this section). In reality, it's as simple as installing just about any other kind of software. At its core, MySQL is powered by a set of data files, stored on your server or local machine, that contain all the information stored in your database. The MySQL software layer on top of that provides a convenient way of interacting with the data, via a command-line interface. For example, the following command digs through the data files and returns a list of all users in your database whose first name is "Ryan":

```
SELECT * FROM users WHERE firstname = "Ryan"
```

If you're on a Debian-based Linux distribution (or anything with `apt-get`), installing MySQL is as easy as this:

```
$ sudo apt-get install mysql-server
```

Just keep an eye on the installation process, approve the memory requirements, and enter a new password for your new root user when prompted.

For macOS and Windows, things are a little trickier. If you haven't already, you need to create an Oracle account before downloading the package.

If you're on macOS, you need to first get the installation package.

Select the *.dmg* package, and log in with or create your Oracle account to download the file. After opening, you should be guided through a fairly straightforward installation wizard (Figure 6-1).

Figure 6-1. The macOS MySQL installer

The default installation steps should suffice, and for the purposes of this book, I assume you have a default MySQL installation.

If downloading and running an installer seems a little tedious, and you're using a Mac, you can always install the package manager, Homebrew. With Homebrew installed, you can also install MySQL by running the following:

```
$ brew install mysql
```

Homebrew is a great open source project with good Python package integration. Most of the third-party Python modules used in this book can be installed easily with Homebrew. If you don't have it already, I highly recommend checking it out!

After MySQL is installed on macOS, you can start the MySQL server as follows:

```
$ cd /usr/local/mysql
$ sudo ./bin/mysqld_safe
```

On Windows, installing and running MySQL is slightly more complicated, but the good news is that a convenient installer simplifies the process. Once downloaded, it will guide you through the steps you need to take (see Figure 6-2).

Figure 6-2. The Windows MySQL Installer

You should be able to install MySQL by using the default selections, with one exception: on the Setup Type page, I recommend you choose Server Only to avoid installing a lot of additional Microsoft software and libraries. From there, you should be able to use the default installation settings and follow the prompts to start your MySQL server.

Some Basic Commands

After your MySQL server is running, you have many options for interacting with the database. Plenty of software tools act as an intermediary so that you don't have to deal with MySQL commands (or at least deal with them less often). Tools such as phpMyAdmin and MySQL Workbench can make it easy to quickly view, sort, and insert data. However, it's still important to know your way around the command line.

Except for variable names, MySQL is case insensitive; for example, `SELECT` is the same as `sElEcT`. However, by convention, all MySQL keywords are in all caps when you are writing a MySQL statement. Conversely, most developers prefer to name their tables and databases in lowercase, although this standard is often ignored.

When you first log into MySQL, there are no databases to add data to, but you can create one:

```
> CREATE DATABASE scraping;
```

Because every MySQL instance can have multiple databases, before you can start interacting with a database, you need to specify to MySQL which database you want to use:

```
> USE scraping;
```

From this point on (at least until you close the MySQL connection or switch to another database), all commands entered will be run against the new `scraping` database.

That all seems pretty straightforward. It must be similarly easy to create a table in the database, right? Let's try to create a table to store a collection of scraped web pages:

```
> CREATE TABLE pages;
```

This results in an error:

```
ERROR 1113 (42000): A table must have at least 1 column
```

Unlike a database, which can exist without any tables, a table in MySQL cannot exist without columns. To define columns in MySQL, you must enter them in a comma-delimited list, within parentheses, after the `CREATE TABLE <tablename>` statement:

```
> CREATE TABLE pages (id BIGINT(7) NOT NULL AUTO_INCREMENT,
title VARCHAR(200), content VARCHAR(10000),
created TIMESTAMP DEFAULT CURRENT_TIMESTAMP, PRIMARY KEY(id));
```

Each column definition has three parts:

- The name (`id`, `title`, `created`, etc.)
- The variable type (`BIGINT(7)`, `VARCHAR`, `TIMESTAMP`)
- Optionally, any additional attributes (`NOT NULL AUTO_INCREMENT`)

At the end of the list of columns, you must define a table's *key*. MySQL uses keys to organize the content in the table for fast lookups. Later in this chapter, I'll describe how to use these keys to your advantage for speedier databases, but for now, using a table's `id` column as the key is generally the best way to go.

After the query executes, you can see what the structure of the table looks like at any time by using `DESCRIBE`:

```
> DESCRIBE pages;
+---------+----------------+------+-----+-------------------+----------------+
| Field   | Type           | Null | Key | Default           | Extra          |
+---------+----------------+------+-----+-------------------+----------------+
| id      | bigint(7)      | NO   | PRI | NULL              | auto_increment |
| title   | varchar(200)   | YES  |     | NULL              |                |
| content | varchar(10000) | YES  |     | NULL              |                |
| created | timestamp      | NO   |     | CURRENT_TIMESTAMP |                |
+---------+----------------+------+-----+-------------------+----------------+
4 rows in set (0.01 sec)
```

Of course, this is still an empty table. You can insert test data into the *pages* table by using the following line:

```
> INSERT INTO pages (title, content) VALUES ("Test page title",
"This is some test page content. It can be up to 10,000 characters
long.");
```

Notice that although the table has four columns (`id`, `title`, `content`, `created`), you need to define only two of them (`title` and `content`) in order to insert a row. That's because the `id` column is autoincremented (MySQL automatically adds a 1 each time a new row is inserted) and generally can take care of itself. In addition, the `timestamp` column is set to contain the current time as a default.

Of course, you *can* override these defaults:

```
> INSERT INTO pages (id, title, content, created) VALUES (3,
"Test page title",
"This is some test page content. It can be up to 10,000 characters
long.", "2014-09-21 10:25:32");
```

As long as the integer you provide for the `id` column doesn't already exist in the database, this override will work perfectly fine. However, it is generally bad practice to do this; it's best to let MySQL handle the `id` and `timestamp` columns unless there is a compelling reason to do it differently.

Now that you have some data in the table, you can use a wide variety of methods to select this data. Here are a few examples of `SELECT` statements:

```
> SELECT * FROM pages WHERE id = 2;
```

This statement tells MySQL, "Select all from pages where `id` equals 2." The asterisk (*) acts as a wildcard, returning all the rows where the clause (`where id equals 2`) is true. It returns the second row in the table, or an empty result if there is no row with an `id` of 2. For example, the following case-insensitive query returns all the rows where the `title` field contains "test" (the % symbol acts as a wildcard in MySQL strings):

```
> SELECT * FROM pages WHERE title LIKE "%test%";
```

But what if you have a table with many columns, and you want only a particular piece of data returned? Rather than selecting all, you can do something like this:

```
> SELECT id, title FROM pages WHERE content LIKE "%page content%";
```

This returns just the `id` and `title` where the content contains the phrase "page content."

`DELETE` statements have much the same syntax as `SELECT` statements:

```
> DELETE FROM pages WHERE id = 1;
```

For this reason, it is a good idea, especially when working on important databases that can't be easily restored, to write any `DELETE` statements as a `SELECT` statement first (in this case, `SELECT * FROM pages WHERE id = 1`), test to make sure only the rows you want to delete are returned, and then replace `SELECT *` with `DELETE`. Many programmers have horror stories of miscoding the clause on a `DELETE` statement, or worse, leaving it off entirely when they were in a hurry, and ruining customer data. Don't let it happen to you!

Similar precautions should be taken with `UPDATE` statements:

```
> UPDATE pages SET title="A new title",
content="Some new content" WHERE id=2;
```

For the purposes of this book, you will be working with only simple MySQL statements, doing basic selecting, inserting, and updating. If you're interested in learning more commands and techniques with this powerful database tool, I recommend Paul DuBois's *MySQL Cookbook* (O'Reilly).

Integrating with Python

Unfortunately, Python support for MySQL is not built in. However, many open source libraries, both with Python 2.x and Python 3.x, allow you to interact with a MySQL database. One of the most popular of these is PyMySQL.

As of this writing, the current version of PyMySQL is 0.6.7, which can be installed using pip:

```
$ pip install PyMySQL
```

You can also download and install it from source, which can be handy if you want to use a specific version of the library:

```
$ curl -L https://pypi.python.org/packages/source/P/PyMySQL/PyMySQL-0.6.7.tar.gz\
| tar xz
$ cd PyMySQL-PyMySQL-f953785/
$ python setup.py install
```

After installation, you should have access to the PyMySQL package automatically. While your local MySQL server is running, you should be able to execute the following script successfully (remember to add the root password for your database):

```
import pymysql
conn = pymysql.connect(host='127.0.0.1', unix_socket='/tmp/mysql.sock',
                       user='root', passwd=None, db='mysql')
cur = conn.cursor()
cur.execute('USE scraping')
cur.execute('SELECT * FROM pages WHERE id=1')
print(cur.fetchone())
cur.close()
conn.close()
```

Two new types of objects are at work in this example: the connection object (`conn`) and the cursor object (`cur`).

The connection/cursor model is commonly used in database programming, although some users might find it tricky to differentiate between the two at first. The connection is responsible for, well, connecting to the database, of course, but also sending the database information, handling rollbacks (when a query or set of queries needs to be aborted, and the database needs to be returned to its previous state), and creating new cursor objects.

A connection can have many cursors. A cursor keeps track of certain *state* information, such as which database it is using. If you have multiple databases and need to write information across all of them, you might have multiple cursors to handle this. A cursor also contains the results of the latest query it has executed. By calling functions on the cursor, such as `cur.fetchone()`, you can access this information.

It is important that both the cursor and the connection are closed after you are finished using them. Not doing this might result in *connection leaks*, a buildup of unclosed connections that are no longer being used, but the software isn't able to close because it's under the impression that you might still use them. This is the sort of thing that brings databases down all the time (I have both written and fixed many connection leak bugs), so remember to close your connections!

The most common thing you'll probably want to do, starting out, is to be able to store your scraping results in a database. Let's take a look at how this could be done, using a previous example: the Wikipedia scraper.

Dealing with Unicode text can be tough when web scraping. By default, MySQL does not handle Unicode. Fortunately, you can turn on this feature (just keep in mind that doing so will increase the size of your database). Because you're bound to run into a variety of colorful characters on Wikipedia, now is a good time to tell your database to expect some Unicode:

```
ALTER DATABASE scraping CHARACTER SET = utf8mb4 COLLATE = utf8mb4_unicode_ci;
ALTER TABLE pages CONVERT TO CHARACTER SET utf8mb4 COLLATE utf8mb4_unicode_ci;
ALTER TABLE pages CHANGE title title VARCHAR(200) CHARACTER SET utf8mb4 COLLATE
utf8mb4_unicode_ci;
ALTER TABLE pages CHANGE content content VARCHAR(10000) CHARACTER SET utf8mb4 CO
LLATE utf8mb4_unicode_ci;
```

These four lines change the default character set for the database, for the table, and for both of the two columns—from `utf8mb4` (still technically Unicode, but with notoriously terrible support for most Unicode characters) to `utf8mb4_unicode_ci`.

You'll know that you're successful if you try inserting a few umlauts or Mandarin characters into the `title` or `content` field in the database and it succeeds with no errors.

Now that the database is prepared to accept a wide variety of all that Wikipedia can throw at it, you can run the following:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import datetime
import random
import pymysql
import re

conn = pymysql.connect(host='127.0.0.1', unix_socket='/tmp/mysql.sock',
                       user='root', passwd=None, db='mysql', charset='utf8')
cur = conn.cursor()
cur.execute("USE scraping")

random.seed(datetime.datetime.now())

def store(title, content):
    cur.execute('INSERT INTO pages (title, content) VALUES '
        '("%s", "%s")', (title, content))
    cur.connection.commit()

def getLinks(articleUrl):
    html = urlopen('http://en.wikipedia.org'+articleUrl)
    bs = BeautifulSoup(html, 'html.parser')
    title = bs.find('h1').get_text()
    content = bs.find('div', {'id':'mw-content-text'}).find('p')
        .get_text()
    store(title, content)
    return bs.find('div', {'id':'bodyContent'}).findAll('a',
        href=re.compile('^(/wiki/)((?!:).)*$'))

links = getLinks('/wiki/Kevin_Bacon')
try:
    while len(links) > 0:
         newArticle = links[random.randint(0, len(links)-1)].attrs['href']
         print(newArticle)
```

```
            links = getLinks(newArticle)
    finally:
        cur.close()
        conn.close()
```

There are a few things to note here: first, `"charset='utf8'"` is added to the database connection string. This tells the connection that it should send all information to the database as UTF-8 (and, of course, the database should already be configured to handle this).

Second, note the addition of a `store` function. This takes in two string variables, `title` and `content`, and adds them to an `INSERT` statement that is executed by the cursor and then committed by the cursor's connection. This is an excellent example of the separation of the cursor and the connection; while the cursor has stored information about the database and its own context, it needs to operate through the connection in order to send information back to the database and insert information.

Last, you'll see that a `finally` statement is added to the program's main loop, at the bottom of the code. This ensures that, regardless of how the program is interrupted or the exceptions that might be thrown during its execution (and because the web is messy, you should always assume exceptions will be thrown), the cursor and the connection will both be closed immediately before the program ends. It is a good idea to include a `try...finally` statement like this whenever you are scraping the web and have an open database connection.

Although PyMySQL is not a huge package, there are a fair number of useful functions that this book can't accommodate. You can check out their documentation at the PyMySQL site.

Database Techniques and Good Practice

Some people spend their entire careers studying, tuning, and inventing databases. I am not one of those people, and this is not that kind of book. However, as with many subjects in computer science, there are a few tricks you can learn quickly to at least make your databases sufficient, and sufficiently speedy, for most applications.

First, with few exceptions, always add `id` columns to your tables. All tables in MySQL must have at least one primary key (the key column that MySQL sorts on), so that MySQL knows how to order it, and it can often be difficult to choose these keys intelligently.

The debate over whether to use an artificially created `id` column for this key or a unique attribute such as `username` has raged among data scientists and software engineers for years, although I tend to lean on the side of creating `id` columns. This is *especially* true when you're dealing with web scraping and storing someone else's

data. You have no idea what's actually unique or not unique, and I've been surprised before.

Your `id` column should be autoincremented and used as the primary key for all of your tables.

Second, use intelligent indexing. A dictionary (like the book, not the Python object) is a list of words indexed alphabetically. This allows quick lookups whenever you need a word, as long as you know how it's spelled. You could also imagine a dictionary that is organized alphabetically by the word's definition. This wouldn't be nearly as useful unless you were playing some strange game of *Jeopardy!* in which a definition was presented and you needed to come up with the word. But in the world of database lookups, these sorts of situations happen. For example, you might have a field in your database that you will often be querying against:

```
>SELECT * FROM dictionary WHERE definition="A small furry animal that says meow";
+------+-------+-------------------------------------+
| id   | word  | definition                          |
+------+-------+-------------------------------------+
|  200 | cat   | A small furry animal that says meow |
+------+-------+-------------------------------------+
1 row in set (0.00 sec)
```

You might very well want to add an index to this table (in addition to the index presumably already in place on the `id`) to the `definition` column in order to make lookups on this column faster. Keep in mind, though, that adding indexing requires more space for the new index, as well as additional processing time when inserting new rows. Especially when you're dealing with large amounts of data, you should carefully consider the trade-offs of your indexes and how much you need to index. To make this "definitions" index a little lighter, you can tell MySQL to index only the first few characters in the column value. This command creates an index on the first 16 characters in the `definition` field:

```
CREATE INDEX definition ON dictionary (id, definition(16));
```

This index will make your lookups much faster when searching for words by their full definition (especially if the first 16 characters in definition values tend to be very different from each other), and also not add too much in the way of extra space and upfront processing time.

On the subject of query time versus database size (one of the fundamental balancing acts in database engineering), one of the common mistakes made, especially with web scraping of large amounts of natural text data, is to store lots of repeating data. For example, say you want to measure the frequency of certain phrases that crop up across websites. These phrases might be found from a given list, or automatically generated via a text-analysis algorithm. You might be tempted to store the data as something like this:

```
+--------+--------------+------+-----+---------+----------------+
| Field  | Type         | Null | Key | Default | Extra          |
+--------+--------------+------+-----+---------+----------------+
| id     | int(11)      | NO   | PRI | NULL    | auto_increment |
| url    | varchar(200) | YES  |     | NULL    |                |
| phrase | varchar(200) | YES  |     | NULL    |                |
+--------+--------------+------+-----+---------+----------------+
```

This adds a row to the database each time you find a phrase on a site and records the URL where it was found. However, by splitting the data into three separate tables, you can shrink your dataset enormously:

```
>DESCRIBE phrases
+--------+--------------+------+-----+---------+----------------+
| Field  | Type         | Null | Key | Default | Extra          |
+--------+--------------+------+-----+---------+----------------+
| id     | int(11)      | NO   | PRI | NULL    | auto_increment |
| phrase | varchar(200) | YES  |     | NULL    |                |
+--------+--------------+------+-----+---------+----------------+

 >DESCRIBE urls
 +-------+--------------+------+-----+---------+----------------+
| Field | Type         | Null | Key | Default | Extra          |
+-------+--------------+------+-----+---------+----------------+
| id    | int(11)      | NO   | PRI | NULL    | auto_increment |
| url   | varchar(200) | YES  |     | NULL    |                |
+-------+--------------+------+-----+---------+----------------+

>DESCRIBE foundInstances
+-------------+---------+------+-----+---------+----------------+
| Field       | Type    | Null | Key | Default | Extra          |
+-------------+---------+------+-----+---------+----------------+
| id          | int(11) | NO   | PRI | NULL    | auto_increment |
| urlId       | int(11) | YES  |     | NULL    |                |
| phraseId    | int(11) | YES  |     | NULL    |                |
| occurrences | int(11) | YES  |     | NULL    |                |
+-------------+---------+------+-----+---------+----------------+
```

Although the table definitions are larger, you can see that the majority of the columns are just integer `id` fields. These take up far less space. In addition, the full text of each URL and phrase is stored exactly once.

Unless you install a third-party package or keep meticulous logs, it can be impossible to tell when a piece of data was added, updated, or removed from your database. Depending on the available space for your data, the frequency of changes, and the importance of determining when those changes happened, you might want to consider keeping several timestamps in place: `created`, `updated`, and `deleted`.

"Six Degrees" in MySQL

Chapter 3 introduced the Six Degrees of Wikipedia problem, in which the goal is to find the connection between any two Wikipedia articles through a series of links (i.e., find a way to get from one Wikipedia article to the next just by clicking links from one page to the next). To solve this problem, it is necessary to not only build bots that can crawl the site (which you have already done), but store the information in an architecturally sound way to make data analysis easy later.

Autoincremented `id` columns, timestamps, and multiple tables: they all come into play here. To figure out how to best store this information, you need to think abstractly. A link is simply something that connects Page A to Page B. It could just as easily connect Page B to Page A, but this would be a separate link. You can uniquely identify a link by saying, "There exists a link on page A, which connects to page B. That is, `INSERT INTO` links (`fromPageId`, `toPageId`) VALUES (A, B); (where A and B are the unique IDs for the two pages)."

A two-table system designed to store pages and links, along with creation dates and unique IDs, can be constructed as follows:

```
CREATE TABLE `wikipedia`.`pages` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `url` VARCHAR(255) NOT NULL,
  `created` TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP,
  PRIMARY KEY (`id`));

CREATE TABLE `wikipedia`.`links` (
  `id` INT NOT NULL AUTO_INCREMENT,
  `fromPageId` INT NULL,
  `toPageId` INT NULL,
  `created` TIMESTAMP NOT NULL DEFAULT CURRENT_TIMESTAMP,
  PRIMARY KEY (`id`));
```

Notice that, unlike with previous crawlers that print the title of the page, you're not even storing the title of the page in the `pages` table. Why is that? Well, recording the title of the page requires that you visit the page to retrieve it. If you want to build an efficient web crawler to fill out these tables, you want to be able to store the page, as well as links to it, even if you haven't necessarily visited the page yet.

Although this doesn't hold true for all sites, the nice thing about Wikipedia links and page titles is that one can be turned into the other through simple manipulation. For example, *http://en.wikipedia.org/wiki/Monty_Python* indicates that the title of the page is "Monty Python."

The following will store all pages on Wikipedia that have a "Bacon number" (the number of links between it and the page for Kevin Bacon, inclusive) of 6 or less:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
```

```
import re
import pymysql
from random import shuffle

conn = pymysql.connect(host='127.0.0.1', unix_socket='/tmp/mysql.sock',
                       user='root', passwd=None, db='mysql', charset='utf8')
cur = conn.cursor()
cur.execute('USE wikipedia')

def insertPageIfNotExists(url):
    cur.execute('SELECT * FROM pages WHERE url = %s', (url))
    if cur.rowcount == 0:
        cur.execute('INSERT INTO pages (url) VALUES (%s)', (url))
        conn.commit()
        return cur.lastrowid
    else:
        return cur.fetchone()[0]

def loadPages():
    cur.execute('SELECT * FROM pages')
    pages = [row[1] for row in cur.fetchall()]
    return pages

def insertLink(fromPageId, toPageId):
    cur.execute('SELECT * FROM links WHERE fromPageId = %s '
        'AND toPageId = %s', (int(fromPageId), int(toPageId)))
    if cur.rowcount == 0:
        cur.execute('INSERT INTO links (fromPageId, toPageId) VALUES (%s, %s)',
                    (int(fromPageId), int(toPageId)))
        conn.commit()


def getLinks(pageUrl, recursionLevel, pages):
    if recursionLevel > 4:
        return

    pageId = insertPageIfNotExists(pageUrl)
    html = urlopen('http://en.wikipedia.org{}'.format(pageUrl))
    bs = BeautifulSoup(html, 'html.parser')
    links = bs.findAll('a', href=re.compile('^(/wiki/)((?!:).)*$'))
    links = [link.attrs['href'] for link in links]

    for link in links:
        insertLink(pageId, insertPageIfNotExists(link))
        if link not in pages:
            # We have encountered a new page, add it and search
            # it for links
            pages.append(link)
            getLinks(link, recursionLevel+1, pages)

getLinks('/wiki/Kevin_Bacon', 0, loadPages())
```

```
    cur.close()
    conn.close()
```

Three functions here use PyMySQL to interface with the database:

`insertPageIfNotExists`
: As its name indicates, this function inserts a new page record if it does not exist already. This, along with the running list of all collected pages stored in `pages`, ensures that page records are not duplicated. It also serves to look up `pageId` numbers in order to create new links.

`insertLink`
: This creates a new link record in the database. It will not create a link if that link already exists. Even if two or more identical links *do* exist on the page, for our purposes, they are the same link, represent the same relationship, and should be counted as only one record. This also helps maintain the integrity of the database if the program is run multiple times, even over the same pages.

`loadPages`
: This loads all current pages from the database into a list, so that it can be determined whether a new page should be visited. Pages are also collected during runtime, so if this crawler is run only once, starting with an empty database, in theory `loadPage` should not be needed. In practice, however, problems may arise. The network might go down, or you might want to collect links over several periods of time, and it's important for the crawler to be able to reload itself and not lose any ground.

You should be aware of one potentially problematic subtlety of using `loadPages`, and the `pages` list it generates in order to determine whether or not to visit a page: as soon as each page is loaded, all the links on that page are stored as pages, even though they have not been visited yet—just their links have been seen. If the crawler is stopped and restarted, all of these "seen but not visited" pages will never be visited, and links coming from them will not be recorded. This might be fixed by adding a boolean `visited` variable to each page record, and setting it to `True` only if that page has been loaded and its own outgoing links recorded.

For our purposes, however, this solution is fine as is. If you can ensure fairly long runtimes (or just a single runtime), and it isn't a necessity to ensure a complete set of links (just a large dataset to experiment with), the addition of the `visited` variable is not necessary.

For the continuation of this problem and the final solution for getting from Kevin Bacon to Eric Idle, see "Six Degrees of Wikipedia: Conclusion" on page 139 on solving directed graph problems.

Email

Just as web pages are sent over HTTP, email is sent over SMTP (Simple Mail Transfer Protocol). And, just as you use a web server client to handle sending out web pages over HTTP, servers use various email clients, such as Sendmail, Postfix, or Mailman, to send and receive email.

Although sending email with Python is relatively easy, it does require that you have access to a server running SMTP. Setting up an SMTP client on your server or local machine is tricky and outside the scope of this book, but many excellent resources can help with this task, particularly if you are running Linux or macOS.

The following code examples assume that you are running an SMTP client locally. (To modify this code for a remote SMTP client, change `localhost` to your remote server's address.)

Sending an email with Python requires just nine lines of code:

```
import smtplib
from email.mime.text import MIMEText

msg = MIMEText('The body of the email is here')

msg['Subject'] = 'An Email Alert'
msg['From'] = 'ryan@pythonscraping.com'
msg['To'] = 'webmaster@pythonscraping.com'

s = smtplib.SMTP('localhost')
s.send_message(msg)
s.quit()
```

Python contains two important packages for sending email: *smtplib* and *email*.

Python's email module contains useful formatting functions for creating email packets to send. The `MIMEText` object, used here, creates an empty email formatted for transfer with the low-level MIME (Multipurpose Internet Mail Extensions) protocol, across which the higher-level SMTP connections are made. The `MIMEText` object, `msg`, contains to/from email addresses, as well as a body and a header, which Python uses to create a properly formatted email.

The smtplib package contains information for handling the connection to the server. Just like a connection to a MySQL server, this connection must be torn down every time it is created, to avoid creating too many connections.

This basic email function can be extended and made more useful by enclosing it in a function:

```
import smtplib
from email.mime.text import MIMEText
from bs4 import BeautifulSoup
```

```
from urllib.request import urlopen
import time

def sendMail(subject, body):
    msg = MIMEText(body)
    msg['Subject'] = subject
    msg['From'] ='christmas_alerts@pythonscraping.com'
    msg['To'] = 'ryan@pythonscraping.com'

    s = smtplib.SMTP('localhost')
    s.send_message(msg)
    s.quit()

bs = BeautifulSoup(urlopen('https://isitchristmas.com/'), 'html.parser')
while(bs.find('a', {'id':'answer'}).attrs['title'] == 'NO'):
    print('It is not Christmas yet.')
    time.sleep(3600)
    bs = BeautifulSoup(urlopen('https://isitchristmas.com/'), 'html.parser')

sendMail('It\'s Christmas!',
         'According to http://itischristmas.com, it is Christmas!')
```

This particular script checks the website *https://isitchristmas.com* (the main feature of which is a giant YES or NO, depending on the day of the year) once an hour. If it sees anything other than a NO, it will send you an email alerting you that it's Christmas.

Although this particular program might not seem much more useful than a calendar hanging on your wall, it can be slightly tweaked to do a variety of extremely useful things. It can email you alerts in response to site outages, test failures, or even the appearance of an out-of-stock product you're waiting for on Amazon—none of which your wall calendar can do.

PART II
Advanced Scraping

You've laid some web scraping groundwork; now comes the fun part. Until this point, your web scrapers have been relatively dumb. They're unable to retrieve information unless it's immediately presented to them in a nice format by the server. They take all information at face value and store it without any analysis. They get tripped up by forms, website interaction, and even JavaScript. In short, they're no good for retrieving information unless that information really wants to be retrieved.

This part of the book will help you analyze raw data to get the story beneath the data—the story that websites often hide beneath layers of JavaScript, login forms, and antiscraping measures. You'll learn how to use web scrapers to test your sites, automate processes, and access the internet on a large scale. By the end of this section, you will have the tools to gather and manipulate nearly any type of data, in any form, across any part of the internet.

CHAPTER 7

Reading Documents

It is tempting to think of the internet primarily as a collection of text-based websites interspersed with newfangled web 2.0 multimedia content that can mostly be ignored for the purposes of web scraping. However, this ignores what the internet most fundamentally is: a content-agnostic vehicle for transmitting files.

Although the internet has been around in some form or another since the late 1960s, HTML didn't debut until 1992. Until then, the internet consisted mostly of email and file transmission; the concept of web pages as we know them today didn't exist. In other words, the internet is not a collection of HTML files. It is a collection of many types of documents, with HTML files often being used as a frame to showcase them. Without being able to read a variety of document types, including text, PDF, images, video, email, and more, we are missing out on a huge part of the available data.

This chapter covers dealing with documents, whether you're downloading them to a local folder or reading them and extracting data. You'll also take a look at dealing with various types of text encoding, which can make it possible to even read foreign-language HTML pages.

Document Encoding

A document's encoding tells applications—whether they are your computer's operating system or your own Python code—how to read it. This encoding can usually be deduced from its file extension, although this file extension is not mandated by its encoding. I could, for example, save *myImage.jpg* as *myImage.txt* with no problems—at least until my text editor tried to open it. Fortunately, this situation is rare, and a document's file extension is usually all you need to know in order to read it correctly.

On a fundamental level, all documents are encoded in 0s and 1s. On top of that, encoding algorithms define things such as "how many bits per character" or "how many bits represent the color for each pixel" (in the case of image files). On top of that, you might have a layer of compression, or some space-reducing algorithm, as is the case with PNG files.

Although dealing with non-HTML files might seem intimidating at first, rest assured that with the right library, Python will be properly equipped to deal with any format of information you want to throw at it. The only difference between a text file, a video file, and an image file is how their 0s and 1s are interpreted. This chapter covers several commonly encountered types of files: text, CSV, PDFs, and Word documents.

Notice that these are all, fundamentally, files that store text. For information about working with images, I recommend that you read through this chapter in order to get used to working with and storing different types of files, and then head to Chapter 13 for more information on image processing!

Text

It is somewhat unusual to have files stored as plain text online, but it is popular among bare-bones or old-school sites to have large repositories of text files. For example, the Internet Engineering Task Force (IETF) stores all of its published documents as HTML, PDF, and text files (see *https://www.ietf.org/rfc/rfc1149.txt* as an example). Most browsers will display these text files just fine, and you should be able to scrape them with no problem.

For most basic text documents, such as the practice file located at *http://www.pythonscraping.com/pages/warandpeace/chapter1.txt*, you can use the following method:

```
from urllib.request import urlopen
textPage = urlopen('http://www.pythonscraping.com/'\
    'pages/warandpeace/chapter1.txt')
print(textPage.read())
```

Normally, when you retrieve a page using `urlopen`, you turn it into a `BeautifulSoup` object in order to parse the HTML. In this case, you can read the page directly. Turning it into a BeautifulSoup object, while perfectly possible, would be counterproductive—there's no HTML to parse, so the library would be useless. Once the text file is read in as a string, you merely have to analyze it as you would any other string read into Python. The disadvantage here, of course, is that you don't have the ability to use HTML tags as context clues, pointing you in the direction of the text you actually need, versus the text you don't want. This can present a challenge when you're trying to extract certain information from text files.

Text Encoding and the Global Internet

Remember earlier when I said a file extension was all you needed to read a file correctly? Well, strangely enough, that rule doesn't apply to the most basic of all documents: the *.txt* file.

Nine times out of 10, reading in text by using the previously described methods will work just fine. However, dealing with text on the internet can be a tricky business. Next, we'll cover the basics of English and foreign-language encoding, from ASCII to Unicode to ISO, and how to deal with them.

A history of text encoding

ASCII was first developed in the 1960s, when bits were expensive and there was no reason to encode anything besides the Latin alphabet and a few punctuation characters. For this reason, only 7 bits were used to encode a total of 128 capitals, lowercase letters, and punctuation. Even with all that creativity, they were still left with 33 non-printing characters, some of which were used, replaced, and/or became obsolete as technologies changed over the years. Plenty of space for everyone, right?

As any programmer knows, 7 is a strange number. It's not a nice power of 2, but it's temptingly close. Computer scientists in the 1960s fought over whether an extra bit should be added for the convenience of having a nice round number versus the practicality of files requiring less storage space. In the end, 7 bits won. However, in modern computing, each 7-bit sequence is padded with an extra 0 at the beginning,[1] leaving us with the worst of both worlds—14% larger files, and the lack of flexibility of only 128 characters.

In the early 1990s, people realized that more languages than just English existed, and that it would be really nice if computers could display them. A nonprofit named The Unicode Consortium attempted to bring about a universal text encoder by establishing encodings for every character that needs to be used in any text document, in any language. The goal was to include everything from the Latin alphabet this book is written in, to Cyrillic (кириллица), Chinese pictograms (象形), math and logic symbols (∑, ≥), and even emoticons and miscellaneous symbols, such as the biohazard sign (☣) and peace symbol (☮).

The resulting encoder, as you might already know, was dubbed *UTF-8*, which stands for, confusingly, "*Universal Character Set—Transformation Format 8 bit*." The *8 bit* here refers, not to the size of every character, but to the smallest size that a character requires to be displayed.

1 This "padding" bit will come back to haunt us with the ISO standards a little later.

The actual size of a UTF-8 character is flexible. They can range from 1 byte to 4 bytes, depending on where they are placed in the list of possible characters (more-popular characters are encoded with fewer bytes, more-obscure ones require more bytes).

How is this flexible encoding achieved? The use of 7 bits with an eventual useless leading 0 looked like a design flaw in ASCII at first, but proved to be a huge advantage for UTF-8. Because ASCII was so popular, Unicode decided to take advantage of this leading 0 bit by declaring all bytes starting with a 0 to indicate that only one byte is used in the character, and making the two encoding schemes for ASCII and UTF-8 identical. Therefore, the following characters are valid in both UTF-8 and ASCII:

```
01000001 - A
01000010 - B
01000011 - C
```

And the following characters are valid only in UTF-8, and will be rendered as nonprintable if the document is interpreted as an ASCII document:

```
11000011 10000000 - À
11000011 10011111 - ß
11000011 10100111 - ç
```

In addition to UTF-8, other UTF standards exist, such as UTF-16, UTF-24, and UTF-32, although documents encoded in these formats are rarely encountered except in unusual circumstances, which are outside the scope of this book.

While this original “design flaw” of ASCII had a major advantage for UTF-8, the disadvantage has not entirely gone away. The first 8 bits of information in each character can still encode only 128 characters, and not a full 256. In a UTF-8 character requiring multiple bytes, additional leading bits are spent, not on character encoding, but on check bits used to prevent corruption. Of the 32 (8 x 4) bits in 4-byte characters, only 21 bits are used for character encoding, for a total of 2,097,152 possible characters, of which, 1,114,112 are currently allocated.

The problem with all universal language-encoding standards, of course, is that any document written in a single foreign language may be much larger than it has to be. Although your language might consist only of 100 or so characters, you will need 16 bits for each character rather than just 8 bits, as is the case for the English-specific ASCII. This makes foreign-language text documents in UTF-8 about twice the size of English-language text documents, at least for foreign languages that don’t use the Latin character set.

ISO solves this problem by creating specific encodings for each language. Like Unicode, it has the same encodings that ASCII does, but uses the padding 0 bit at the beginning of every character to allow it to create 128 special characters for all languages that require them. This works best for European languages that also rely heavily on the Latin alphabet (which remain in positions 0–127 in the encoding), but

require additional special characters. This allows ISO-8859-1 (designed for the Latin alphabet) to have symbols such as fractions (e.g., ½) or the copyright sign (©).

Other ISO character sets, such as ISO-8859-9 (Turkish), ISO-8859-2 (German, among other languages), and ISO-8859-15 (French, among other languages) can also be found on the internet with some regularity.

Although the popularity of ISO-encoded documents has been declining in recent years, about 9% of websites on the internet are still encoded with some flavor of ISO,[2] making it essential to know about and check for encodings before scraping a site.

Encodings in action

In the previous section, you used the default settings for `urlopen` to read text documents you might encounter on the internet. This works great for most English text. However, the second you encounter Russian, Arabic, or even a word like "résumé," you might run into problems.

Take the following code, for example:

```
from urllib.request import urlopen
textPage = urlopen('http://www.pythonscraping.com/'\
    'pages/warandpeace/chapter1-ru.txt')
print(textPage.read())
```

This reads in the first chapter of the original *War and Peace* (written in Russian and French) and prints it to the screen. This screen text reads, in part:

```
b"\xd0\xa7\xd0\x90\xd0\xa1\xd0\xa2\xd0\xac \xd0\x9f\xd0\x95\xd0\xa0\xd0\x92\xd0\
x90\xd0\xaf\n\nI\n\n\xe2\x80\x94 Eh bien, mon prince.
```

In addition, visiting this page in most browsers results in gibberish (see Figure 7-1).

2 According to W3Techs, which uses web crawlers to gather these sorts of statistics.

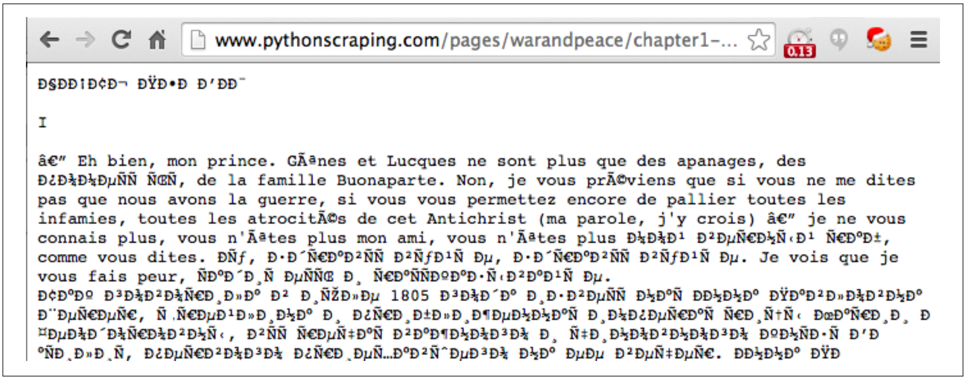


Figure 7-1. French and Cyrillic text encoded in ISO-8859-1, the default text document encoding in many browsers

Even for native Russian speakers, that might be a bit difficult to make sense of. The problem is that Python is attempting to read the document as an ASCII document, whereas the browser is attempting to read it as an ISO-8859-1 encoded document. Neither one, of course, realizes it's a UTF-8 document.

You can explicitly define the string to be UTF-8, which correctly formats the output into Cyrillic characters:

```
from urllib.request import urlopen

textPage = urlopen('http://www.pythonscraping.com/'\
    'pages/warandpeace/chapter1-ru.txt')
print(str(textPage.read(), 'utf-8'))
```

Using this concept in BeautifulSoup and Python 3.x looks like this:

```
html = urlopen('http://en.wikipedia.org/wiki/Python_(programming_language)')
bs = BeautifulSoup(html, 'html.parser')
content = bs.find('div', {'id':'mw-content-text'}).get_text()
content = bytes(content, 'UTF-8')
content = content.decode('UTF-8')
```

Python 3.x encodes all characters into UTF-8 by default. You might be tempted to leave this alone and use UTF-8 encoding for every web scraper you write. After all, UTF-8 will also handle ASCII characters as well as foreign languages smoothly. However, it's important to remember the 9% of websites out there that use some version of ISO encoding as well, so you can never avoid this problem entirely.

Unfortunately, in the case of text documents, it's impossible to concretely determine what encoding a document has. Some libraries can examine the document and make a best guess (using a little logic to realize that "Ñ€Ð°ÑÑÐºÐ°Ð·Ñ" is probably not a word), but many times it's wrong.

Fortunately, in the case of HTML pages, the encoding is usually contained in a tag found in the `<head>` section of the site. Most sites, particularly English-language sites, have this tag:

```
<meta charset="utf-8" />
```

Whereas the ECMA International's website has this tag:[3]

```
<META HTTP-EQUIV="Content-Type" CONTENT="text/html; charset=iso-8859-1">
```

If you plan on doing a lot of web scraping, particularly of international sites, it might be wise to look for this meta tag and use the encoding it recommends when reading the contents of the page.

CSV

When web scraping, you are likely to encounter either a CSV file or a coworker who likes data formatted in this way. Fortunately, Python has a fantastic library for both reading and writing CSV files. Although this library is capable of handling many variations of CSV, this section focuses primarily on the standard format. If you have a special case you need to handle, consult the documentation!

Reading CSV Files

Python's *csv* library is geared primarily toward working with local files, on the assumption that the CSV data you need is stored on your machine. Unfortunately, this isn't always the case, especially when you're web scraping. There are several ways to work around this:

- Download the file locally by hand and point Python at the local file location.
- Write a Python script to download the file, read it, and (optionally) delete it after retrieval.
- Retrieve the file as a string from the web, and wrap the string in a `StringIO` object so that it behaves like a file.

Although the first two options are workable, taking up hard drive space with files when you could easily keep them in memory is bad practice. It's much better to read the file in as a string and wrap it in an object that allows Python to treat it as a file, without ever saving the file. The following script retrieves a CSV file from the internet (in this case, a list of Monty Python albums at *http://pythonscraping.com/files/MontyPythonAlbums.csv*) and prints it, row by row, to the terminal:

3 ECMA was one of the original contributors to the ISO standard, so it's no surprise its website is encoded with a flavor of ISO.

```
from urllib.request import urlopen
from io import StringIO
import csv

data = urlopen('http://pythonscraping.com/files/MontyPythonAlbums.csv')
              .read().decode('ascii', 'ignore')
dataFile = StringIO(data)
csvReader = csv.reader(dataFile)

for row in csvReader:
    print(row)
```

The output looks like this:

```
['Name', 'Year']
["Monty Python's Flying Circus", '1970']
['Another Monty Python Record', '1971']
["Monty Python's Previous Record", '1972']
...
```

As you can see from the code sample, the reader object returned by `csv.reader` is iterable and composed of Python list objects. Because of this, each row in the `csvReader` object is accessible in the following way:

```
for row in csvReader:
    print('The album "'+row[0]+'" was released in '+str(row[1]))
```

Here is the output:

```
The album "Name" was released in Year
The album "Monty Python's Flying Circus" was released in 1970
The album "Another Monty Python Record" was released in 1971
The album "Monty Python's Previous Record" was released in 1972
...
```

Notice the first line: `The album "Name" was released in Year`. Although this might be an easy-to-ignore result when writing example code, you don't want this getting into your data in the real world. A lesser programmer might simply skip the first row in the `csvReader` object, or write in a special case to handle it. Fortunately, an alternative to the `csv.reader` function takes care of all of this for you automatically. Enter `DictReader`:

```
from urllib.request import urlopen
from io import StringIO
import csv

data = urlopen('http://pythonscraping.com/files/MontyPythonAlbums.csv')
              .read().decode('ascii', 'ignore')
dataFile = StringIO(data)
dictReader = csv.DictReader(dataFile)

print(dictReader.fieldnames)
```

```
for row in dictReader:
    print(row)
```

`csv.DictReader` returns the values of each row in the CSV file as dictionary objects rather than list objects, with field names stored in the variable `dictReader.fieldnames` and as keys in each dictionary object:

```
['Name', 'Year']
{'Name': 'Monty Python's Flying Circus', 'Year': '1970'}
{'Name': 'Another Monty Python Record', 'Year': '1971'}
{'Name': 'Monty Python's Previous Record', 'Year': '1972'}
```

The downside, of course, is that it takes slightly longer to create, process, and print these `DictReader` objects as opposed to `csvReader`, but the convenience and usability is often worth the additional overhead. Also keep in mind that, when it comes to web scraping, the overhead required for requesting and retrieving website data from an external server will almost always be the unavoidable limiting factor in any program you write, so worrying about which technique might shave microseconds off your total runtime is often a moot point!

PDF

As a Linux user, I know the pain of being sent a *.docx* file that my non-Microsoft software mangles and struggling trying to find the codecs to interpret some new Apple media format. In some ways, Adobe was revolutionary in creating its Portable Document Format in 1993. PDFs allowed users on different platforms to view image and text documents in exactly the same way, regardless of the platform they were viewing it on.

Although storing PDFs on the web is somewhat passé (why store content in a static, slow-loading format when you could write it up as HTML?), PDFs remain ubiquitous, particularly when dealing with official forms and filings.

In 2009, a Briton named Nick Innes made the news when he requested public student test result information from the Buckinghamshire City Council, which was available under the United Kingdom's version of the Freedom of Information Act. After some repeated requests and denials, he finally received the information he was looking for —in the form of 184 PDF documents.

Although Innes persisted and eventually received a more properly formatted database, had he been an expert web scraper, he likely could have saved himself a lot of time in the courts and used the PDF documents directly, with one of Python's many PDF-parsing modules.

Unfortunately, many of the PDF-parsing libraries built for Python 2.x were not upgraded with the launch of Python 3.x. However, because the PDF is a relatively

simple and open source document format, many decent Python libraries, even in Python 3.x, can read them.

PDFMiner3K is one such relatively easy-to-use library. It is flexible, allowing for command-line usage or integration into existing code. It can also handle a variety of language encodings—again, something that often comes in handy on the web.

You can install as usual using pip, or download this Python module and install it by unzipping the folder and running the following:

```
$ python setup.py install
```

The documentation is located at */pdfminer3k-1.3.0/docs/index.html* within the extracted folder, although the current documentation tends to be geared more toward the command-line interface than integration with Python code.

Here is a basic implementation that allows you to read arbitrary PDFs to a string, given a local file object:

```
from urllib.request import urlopen
from pdfminer.pdfinterp import PDFResourceManager, process_pdf
from pdfminer.converter import TextConverter
from pdfminer.layout import LAParams
from io import StringIO
from io import open

def readPDF(pdfFile):
    rsrcmgr = PDFResourceManager()
    retstr = StringIO()
    laparams = LAParams()
    device = TextConverter(rsrcmgr, retstr, laparams=laparams)

    process_pdf(rsrcmgr, device, pdfFile)
    device.close()

    content = retstr.getvalue()
    retstr.close()
    return content

pdfFile = urlopen('http://pythonscraping.com/'
    'pages/warandpeace/chapter1.pdf')
outputString = readPDF(pdfFile)
print(outputString)
pdfFile.close()
```

This gives the familiar plain-text output:

```
CHAPTER I

"Well, Prince, so Genoa and Lucca are now just family estates of
the Buonapartes. But I warn you, if you don't tell me that this
means war, if you still try to defend the infamies and horrors
perpetrated by that Antichrist- I really believe he is Antichrist- I will
```

The nice thing about this PDF reader is that if you're working with files locally, you can substitute a regular Python file object for the one returned by `urlopen` and use this line:

```
pdfFile = open('../pages/warandpeace/chapter1.pdf', 'rb')
```

The output might not be perfect, especially for PDFs with images, oddly formatted text, or text arranged in tables or charts. However, for most text-only PDFs, the output should be no different than if the PDF were a text file.

Microsoft Word and .docx

At the risk of offending my friends at Microsoft: I do not like Microsoft Word. Not because it's necessarily a bad piece of software, but because of the way its users misuse it. It has a particular talent for turning what should be simple text documents or PDFs into large, slow, difficult-to-open beasts that often lose all formatting from machine to machine, and are, for whatever reason, editable when the content is often meant to be static.

Word files are designed for content creation, not content sharing. Nevertheless, they are ubiquitous on certain sites, containing important documents, information, and even charts and multimedia; in short, everything that can and should be created with HTML.

Before about 2008, Microsoft Office products used the proprietary *.doc* file format. This binary-file format was difficult to read and poorly supported by other word processors. In an effort to get with the times and adopt a standard that was used by many other pieces of software, Microsoft decided to use the Open Office XML-based standard, which made the files compatible with open source and other software.

Unfortunately, Python's support for this file format, used by Google Docs, Open Office, and Microsoft Office, still isn't great. There is the python-docx library, but this only gives users the ability to create documents and read only basic file data such as the size and title of the file, not the actual contents. To read the contents of a Microsoft Office file, you'll need to roll your own solution.

The first step is to read the XML from the file:

```
from zipfile import ZipFile
from urllib.request import urlopen
from io import BytesIO

wordFile = urlopen('http://pythonscraping.com/pages/AWordDocument.docx').read()
wordFile = BytesIO(wordFile)
document = ZipFile(wordFile)
xml_content = document.read('word/document.xml')
print(xml_content.decode('utf-8'))
```

This reads a remote Word document as a binary file object (`BytesIO` is analogous to `StringIO`, used earlier in this chapter), unzips it using Python's core zipfile library (all *.docx* files are zipped to save space), and then reads the unzipped file, which is XML.

The Word document at *http://pythonscraping.com/pages/AWordDocument.docx* is shown in Figure 7-2.

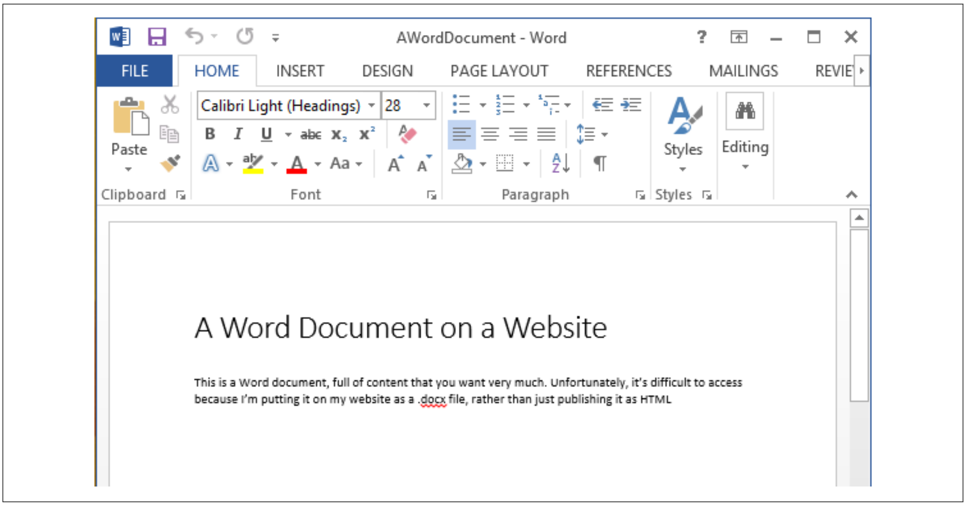


Figure 7-2. This is a Word document that's full of content you might want very much, but it's difficult to access because I'm putting it on my website as a .docx file instead of publishing it as HTML

The output of the Python script reading my simple Word document is the following:

```
<!--?xml version="1.0" encoding="UTF-8" standalone="yes"?-->
<w:document mc:ignorable="w14 w15 wp14" xmlns:m="http://schemas.openx
mlformats.org/officeDocument/2006/math" xmlns:mc="http://schemas.open
xmlformats.org/markup-compatibility/2006" xmlns:o="urn:schemas-micros
oft-com:office:office" xmlns:r="http://schemas.openxmlformats.org/off
iceDocument/2006/relationships" xmlns:v="urn:schemas-microsoft-com:vm
l" xmlns:w="http://schemas.openxmlformats.org/wordprocessingml/2006/m
ain" xmlns:w10="urn:schemas-microsoft-com:office:word" xmlns:w14="htt
p://schemas.microsoft.com/office/word/2010/wordml" xmlns:w15="http://
schemas.microsoft.com/office/word/2012/wordml" xmlns:wne="http://sche
mas.microsoft.com/office/word/2006/wordml" xmlns:wp="http://schemas.o
penxmlformats.org/drawingml/2006/wordprocessingDrawing" xmlns:wp14="h
ttp://schemas.microsoft.com/office/word/2010/wordprocessingDrawing" x
mlns:wpc="http://schemas.microsoft.com/office/word/2010/wordprocessin
gCanvas" xmlns:wpg="http://schemas.microsoft.com/office/word/2010/wor
dprocessingGroup" xmlns:wpi="http://schemas.microsoft.com/office/word
/2010/wordprocessingInk" xmlns:wps="http://schemas.microsoft.com/offi
ce/word/2010/wordprocessingShape"><w:body><w:p w:rsidp="00764658" w:r
```

```
sidr="00764658" w:rsidrdefault="00764658"><w:ppr><w:pstyle w:val="Tit
le"></w:pstyle></w:ppr><w:r><w:t>A Word Document on a Website</w:t></
w:r><w:bookmarkstart w:id="0" w:name="_GoBack"></w:bookmarkstart><w:b
ookmarkend w:id="0"></w:bookmarkend></w:p><w:p w:rsidp="00764658" w:r
sidr="00764658" w:rsidrdefault="00764658"></w:p><w:p w:rsidp="0076465
8" w:rsidr="00764658" w:rsidrdefault="00764658" w:rsidrpr="00764658">
<w: r> <w:t>This is a Word document, full of content that you want ve
ry much. Unfortunately, it's difficult to access because I'm putting
it on my website as a .</w:t></w:r><w:prooferr w:type="spellStart"></
w:prooferr><w:r><w:t>docx</w:t></w:r><w:prooferr w:type="spellEnd"></
w:prooferr> <w:r> <w:t xml:space="preserve"> file, rather than just p
ublishing it as HTML</w:t> </w:r> </w:p> <w:sectpr w:rsidr="00764658"
 w:rsidrpr="00764658"> <w:pgszw:h="15840" w:w="12240"></w:pgsz><w:pgm
ar w:bottom="1440" w:footer="720" w:gutter="0" w:header="720" w:left=
"1440" w:right="1440" w:top="1440"></w:pgmar> <w:cols w:space="720"><
/w:cols&g; <w:docgrid w:linepitch="360"></w:docgrid> </w:sectpr> </w:
body> </w:document>
```

There's clearly a lot of metadata here, but the actual text content you want is buried. Fortunately, all of the text in the document, including the title at the top, is contained in `w:t` tags, which makes it easy to grab:

```
from zipfile import ZipFile
from urllib.request import urlopen
from io import BytesIO
from bs4 import BeautifulSoup

wordFile = urlopen('http://pythonscraping.com/pages/AWordDocument.docx').read()
wordFile = BytesIO(wordFile)
document = ZipFile(wordFile)
xml_content = document.read('word/document.xml')

wordObj = BeautifulSoup(xml_content.decode('utf-8'), 'xml')
textStrings = wordObj.find_all('w:t')

for textElem in textStrings:
    print(textElem.text)
```

Note that instead of the *html.parser* parser that you normally use with `BeautifulSoup`, you're passing it the *xml* parser. This is because colons are nonstandard in HTML tag names like `w:t` and *html.parser* does not recognize them.

The output isn't perfect but it's getting there, and printing each `w:t` tag on a new line makes it easy to see how Word is splitting up the text:

```
A Word Document on a Website
This is a Word document, full of content that you want very much. Unfortunately,
it's difficult to access because I'm putting it on my website as a .
docx
 file, rather than just publishing it as HTML
```

Notice that the word "docx" is on its own line. In the original XML, it is surrounded with the tag `<w:proofErr w:type="spellStart"/>`. This is Word's way of highlighting "docx" with the red squiggly underline, indicating that it believes there's a spelling error in the name of its own file format.

The title of the document is preceded by the style descriptor tag `<w:pstyle w:val="Title">`. Although this doesn't make it extremely easy for us to identify titles (or other styled text) as such, using BeautifulSoup's navigation features can be useful:

```
textStrings = wordObj.find_all('w:t')

for textElem in textStrings:
    style = textElem.parent.parent.find('w:pStyle')
    if style is not None and style['w:val'] == 'Title':
        print('Title is: {}'.format(textElem.text))
    else:
        print(textElem.text)
```

This function can be easily expanded to print tags around a variety of text styles or label them in some other way.

CHAPTER 8

Cleaning Your Dirty Data

So far in this book, you've ignored the problem of badly formatted data by using generally well-formatted data sources, dropping data entirely if it deviated from what you were expecting. But often, in web scraping, you can't be too picky about where you get your data from, or what it looks like.

Because of errant punctuation, inconsistent capitalization, line breaks, and misspellings, dirty data can be a big problem on the web. This chapter covers a few tools and techniques to help you prevent the problem at the source by changing the way you write code, and clean the data after it's in the database.

Cleaning in Code

Just as you write code to handle overt exceptions, you should practice defensive coding to handle the unexpected.

In linguistics, an *n-gram* is a sequence of *n* words used in text or speech. When doing natural language analysis, it can often be handy to break up a piece of text by looking for commonly used n-grams, or recurring sets of words that are often used together.

This section focuses on obtaining properly formatted n-grams rather than using them to do any analysis. Later, in Chapter 9, you can see 2-grams and 3-grams in action to do text summarization and analysis.

The following returns a list of 2-grams found in the Wikipedia article on the Python programming language:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup

def getNgrams(content, n):
  content = content.split(' ')
```

```
  output = []
  for i in range(len(content)-n+1):
    output.append(content[i:i+n])
  return output

html = urlopen('http://en.wikipedia.org/wiki/Python_(programming_language)')
bs = BeautifulSoup(html, 'html.parser')
content = bs.find('div', {'id':'mw-content-text'}).get_text()
ngrams = getNgrams(content, 2)
print(ngrams)
print('2-grams count is: '+str(len(ngrams)))
```

The `getNgrams` function takes in an input string, splits it into a sequence of words (assuming all words are separated by spaces), and adds the n-gram (in this case, a 2-gram) that each word starts into an array.

This returns some genuinely interesting and useful 2-grams from the text:

```
['of', 'free'], ['free', 'and'], ['and', 'open-source'], ['open-source', 'softwa
re']
```

But it also returns a lot of junk:

```
['software\nOutline\nSPDX\n\n\n\n\n\n\n\n\nOperating', 'system\nfamilies\n\n\n\n
AROS\nBSD\nDarwin\neCos\nFreeDOS\nGNU\nHaiku\nInferno\nLinux\nMach\nMINIX\nOpenS
olaris\nPlan'], ['system\nfamilies\n\n\n\nAROS\nBSD\nDarwin\neCos\nFreeDOS\nGNU\
nHaiku\nInferno\nLinux\nMach\nMINIX\nOpenSolaris\nPlan', '9\nReactOS\nTUD:OS\n\n
\n\n\n\n\n\nDevelopment\n\n\n\nBasic'], ['9\nReactOS\nTUD:OS\n\n\n\n\n\n\n\n\n
Development\n\n\n\nBasic', 'For']
```

In addition, because a 2-gram is created for each and every word encountered (except for the last one), there are 7,411 2-grams in the article at the time of this writing. Not a very manageable dataset!

Using regular expressions to remove escape characters (such as `\n`) and filtering to remove any Unicode characters, you can clean up the output somewhat:

```
import re

def getNgrams(content, n):
    content = re.sub('\n|[[\d+\]]', ' ', content)
    content = bytes(content, 'UTF-8')
    content = content.decode('ascii', 'ignore')
    content = content.split(' ')
    content = [word for word in content if word != '']
    output = []
    for i in range(len(content)-n+1):
        output.append(content[i:i+n])
    return output
```

This replaces all instances of the newline character with a space, removes citations like `[123]`, and filters out all empty strings, caused by multiple spaces in a row. Then, escape characters are eliminated by encoding the content with UTF-8.

These steps greatly improve the output of the function, but some issues still remain:

```
['years', 'ago('], ['ago(', '-'], ['-', '-'], ['-', ')'], [')', 'Stable']
```

You can improve on this by removing all punctuation before and after each word (stripping the punctuation). This preserves things like hyphens within words, but eliminates strings that consist of only a single punctuation mark after empty strings are eliminated.

Of course, punctuation itself has meaning, and simply removing it may result in losing some valuable information. For instance, a period followed by a space can be assumed to mean the end of a complete sentence or statement. You may want to disallow n-grams that bridge over a stop like this and consider only ones created within the sentence.

For instance, given the text

```
Python features a dynamic type system and automatic memory management.
It supports multiple programming paradigms...
```

the 2-gram `['memory', 'management']` would be valid, but the 2-gram `['management', 'It']` would not.

Now that you have a longer list of "cleaning tasks," you're introducing the concept of "sentences," and your program has become generally more complex, it's best to move these out into four different functions:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re
import string

def cleanSentence(sentence):
    sentence = sentence.split(' ')
    sentence = [word.strip(string.punctuation+string.whitespace)
        for word in sentence]
    sentence = [word for word in sentence if len(word) > 1
        or (word.lower() == 'a' or word.lower() == 'i')]
    return sentence

def cleanInput(content):
    content = re.sub('\n|[[\d+\]]', ' ', content)
    content = bytes(content, "UTF-8")
    content = content.decode("ascii", "ignore")
    sentences = content.split('. ')
    return [cleanSentence(sentence) for sentence in sentences]

def getNgramsFromSentence(content, n):
    output = []
    for i in range(len(content)-n+1):
        output.append(content[i:i+n])
    return output
```

```
def getNgrams(content, n):
    content = cleanInput(content)
    ngrams = []
    for sentence in content:
        ngrams.extend(getNgramsFromSentence(sentence, n))
    return(ngrams)
```

`getNgrams` remains as your basic entry point into the program. `cleanInput` removes newlines and citations, as before, but also splits the text into "sentences" based on the location of periods followed by a space. It also calls `cleanSentence`, which splits the sentence into words, strips punctuation and whitespace, and removes single-character words besides *I* and *a*.

The key lines that create the n-grams are moved into `getNgramsFromSentence`, which is called on each sentence by `getNgrams`. This ensures that n-grams are not created that span multiple sentences.

Note the use of `string.punctuation` and `string.whitespace` to get a list of all punctuation characters in Python. You can view the output of `string.punctuation` from a Python terminal:

```
>>> import string
>>> print(string.punctuation)
!"#$%&'()*+,-./:;<=>?@[\]^_`{|}~
```

`print(string.whitespace)` produces much less interesting output (after all, it's just whitespace), but contains whitespace characters including nonbreaking spaces, tabs, and newlines.

By using `item.strip(string.punctuation+string.whitespace)` inside a loop iterating through all words in the content, any punctuation characters on either side of the word will be stripped, although hyphenated words (where the punctuation character is bounded by letters on either side) will remain untouched.

The output of this effort results in much cleaner 2-grams:

```
[['Python', 'Paradigm'], ['Paradigm', 'Object-oriented'], ['Object-oriented',
'imperative'], ['imperative', 'functional'], ['functional', 'procedural'],
['procedural', 'reflective'],...
```

Data Normalization

Everyone has encountered a poorly designed web form: "Enter your phone number. Your phone number must be in the form 'xxx-xxx-xxxx'."

As a good programmer, you will likely think to yourself, "Why don't they just strip out the non-numeric characters I put in there and do it themselves?" *Data normalization* is the process of ensuring that strings that are linguistically or logically equivalent

to each other, such as the phone numbers (555) 123-4567 and 555.123.4567, are displayed, or at least compared, as equivalent.

Using the n-gram code from the previous section, you can add data normalization features.

One obvious problem with this code is that it contains many duplicate 2-grams. Every 2-gram it encounters gets added to the list, with no record of its frequency. Not only is it interesting to record the frequency of these 2-grams, rather than just their existence, but it can be useful in charting the effects of changes to the cleaning and data normalization algorithms. If data is normalized successfully, the total number of unique n-grams will be reduced, while the total count of n-grams found (i.e., the number of unique or nonunique items identified as n-grams) will not be reduced. In other words, there will be fewer "buckets" for the same number of n-grams.

You can do this by modifying the code that collects the n-grams to add them to a `Counter` object, rather than a list:

```
from collections import Counter

def getNgrams(content, n):
    content = cleanInput(content)
    ngrams = Counter()
    for sentence in content:
        newNgrams = [' '.join(ngram) for ngram in
            getNgramsFromSentence(sentence, 2)]
        ngrams.update(newNgrams)
    return(ngrams)
```

There are many other ways to do this, such as adding n-grams to a dictionary object in which the value of the list points at a count for the number of times it was seen. That has a disadvantage in that it requires a bit more management and makes sorting tricky. However, using a `Counter` object also has a disadvantage: it cannot store lists (lists are unhashable), so you need to convert them to strings first by using a `' '.join(ngram)` inside a list comprehension for each n-gram.

Here are the results:

```
Counter({'Python Software': 37, 'Software Foundation': 37, 'of the': 34,
'of Python': 28, 'in Python': 24, 'in the': 23, 'van Rossum': 20, 'to the':
20, 'such as': 19, 'Retrieved February': 19, 'is a': 16, 'from the': 16,
'Python Enhancement': 15,...
```

As of this writing, there are 7,275 total 2-grams and 5,628 unique 2-grams, with the most popular 2-gram being "Software Foundation," followed by "Python Software." However, analysis of the results shows that "Python Software" appears in the form of "Python software" an additional two times. Similarly, both "van Rossum" and "Van Rossum" make an appearance in the list separately.

Adding the line

```
content = content.upper()
```

to the `cleanInput` function keeps the total number of 2-grams found steady at 7,275, while decreasing the number of unique 2-grams to 5,479.

Beyond this, it's usually good to stop and consider how much computing power you want to expend normalizing data. There are a number of situations in which different spellings of words are equivalent, but in order to resolve this equivalency, you need to run a check on every single word to see whether it matches any of your preprogrammed equivalencies.

For example, "Python 1st" and "Python first" both appear in the list of 2-grams. However, to make a blanket rule that says, "All first, second, third, etc., will be resolved to 1st, 2nd, 3rd, etc. (or vice versa)" would result in an additional 10 or so checks per word.

Similarly, the inconsistent use of hyphens ("co-ordinated" versus "coordinated"), misspellings, and other natural language incongruities will affect the groupings of n-grams, and might muddy the results of the output if the incongruities are common enough.

One solution, in the case of hyphenated words, might be to remove hyphens entirely and treat the word as a single string, which would require only a single operation. However, this would also mean that hyphenated phrases (an all-too-common occurrence) will be treated as a single word. Going the other route and treating hyphens as spaces might be a better option. Just be prepared for the occasional "co ordinated" and "ordinated attack" to slip in!

Cleaning After the Fact

There is only so much you can (or want to) do in code. In addition, you might be dealing with a dataset that you didn't create, or a dataset that would be a challenge to even know how to clean without seeing it first.

A knee-jerk reaction that many programmers have in this sort of situation is "write a script," which can be an excellent solution. However, third-party tools, such as OpenRefine, also are capable of not only cleaning data quickly and easily, but allowing your data to be easily seen and used by nonprogrammers.

OpenRefine

OpenRefine is an open source project started by a company called Metaweb in 2009. Google acquired Metaweb in 2010, changing the name of the project from Freebase Gridworks to Google Refine. In 2012, Google dropped support for Refine and

changed the name again, to OpenRefine, and anyone is welcome to contribute to the development of the project.

Installation

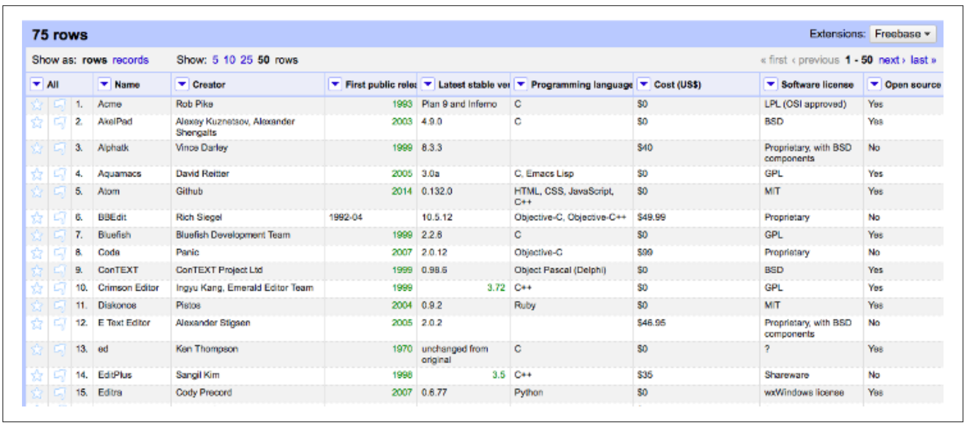
OpenRefine is unusual in that although its interface is run in a browser, it is technically a desktop application that must be downloaded and installed. You can download the application for Linux, Windows, and macOS from its website.

> If you're a Mac user and run into any trouble opening the file, go to System Preferences → Security & Privacy → General. Under "Allow apps downloaded from," select Anywhere. Unfortunately, during the transition from a Google project to an open source project, OpenRefine appears to have lost its legitimacy in the eyes of Apple.

To use OpenRefine, you need to save your data as a CSV file (refer to "Storing Data to CSV" on page 86 if you need a refresher on how to do this). Alternatively, if you have your data stored in a database, you might be able to export it to a CSV file.

Using OpenRefine

In the following examples, you'll use data scraped from Wikipedia's "Comparison of Text Editors" table; see Figure 8-1. Although this table is relatively well formatted, it contains many edits by people over a long time, so it has a few minor formatting inconsistencies. In addition, because its data is meant to be read by humans rather than machines, some of the formatting choices (e.g., using "Free" rather than "$0.00") are inappropriate for programming inputs.


75 rows
Extensions: Freebase
Show as: rows records   Show: 5 10 25 50 rows
« first ‹ previous 1 - 50 next › last »

All	Name	Creator	First public rele	Latest stable ver	Programming language	Cost (US$)	Software license	Open source
1.	Acme	Rob Pike	1993	Plan 9 and Inferno	C	$0	LPL (OSI approved)	Yes
2.	AkelPad	Alexey Kuznetsov, Alexander Shengalts	2003	4.9.0	C	$0	BSD	Yes
3.	Alphatk	Vince Darley	1999	8.3.3		$40	Proprietary, with BSD components	No
4.	Aquamacs	David Reitter	2005	3.0a	C, Emacs Lisp	$0	GPL	Yes
5.	Atom	Github	2014	0.132.0	HTML, CSS, JavaScript, C++	$0	MIT	Yes
6.	BBEdit	Rich Siegel	1992-04	10.5.12	Objective-C, Objective-C++	$49.99	Proprietary	No
7.	Bluefish	Bluefish Development Team	1999	2.2.6	C	$0	GPL	Yes
8.	Coda	Panic	2007	2.0.12	Objective-C	$99	Proprietary	No
9.	ConTEXT	ConTEXT Project Ltd	1999	0.98.6	Object Pascal (Delphi)	$0	BSD	Yes
10.	Crimson Editor	Ingyu Kang, Emerald Editor Team	1999	3.72	C++	$0	GPL	Yes
11.	Diakonos	Pistos	2004	0.9.2	Ruby	$0	MIT	Yes
12.	E Text Editor	Alexander Stigsen	2005	2.0.2		$46.95	Proprietary, with BSD components	No
13.	ed	Ken Thompson	1970	unchanged from original	C	$0	?	Yes
14.	EditPlus	Sangil Kim	1998	3.5	C++	$35	Shareware	No
15.	Editra	Cody Precord	2007	0.6.77	Python	$0	wxWindows license	Yes

Figure 8-1. Data from Wikipedia's "Comparison of Text Editors," as shown in the main OpenRefine screen

The first thing to note about OpenRefine is that each column label has an arrow next to it. This arrow provides a menu of tools that can be used with that column for filtering, sorting, transforming, or removing data.

Filtering. Data filtering can be performed using two methods: filters and facets. Filters are good for using regular expressions to filter the data; for example, "Show me only data that contains three or more comma-separated programming languages in the Programming language column," as seen in Figure 8-2.

Filters can be combined, edited, and added easily by manipulating the blocks in the righthand column. They also can be combined with facets.

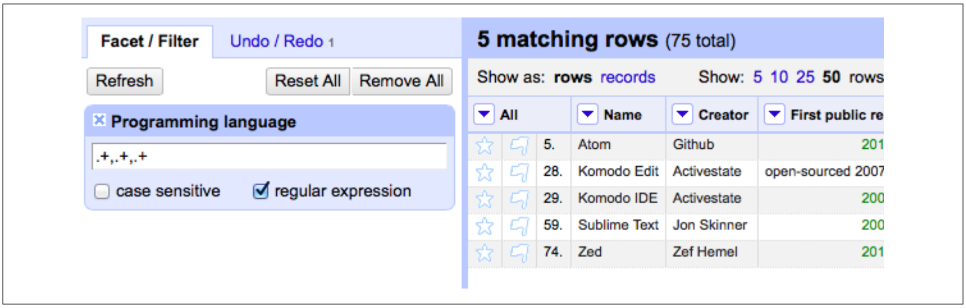


Figure 8-2. The regular expression ".+,.+,.+" selects for values that have at least three comma-separated items

Facets are great for including or excluding data based on the entire contents of the column. (e.g., "Show all rows that use the GPL or MIT license, and were first released after 2005," as seen in Figure 8-3). They have built-in filtering tools. For instance, filtering on a numeric value provides you with slide bars to select the value range that you want to include.

Figure 8-3. This displays all text editors using the GPL or MIT license that had their first public release after 2005

However you filter your data, it can be exported at any point to one of several types of formats that OpenRefine supports. This includes CSV, HTML (an HTML table), Excel, and several other formats.

Cleaning. Data filtering can be done successfully only if the data is relatively clean to start with. For instance, in the facet example in the previous section, a text editor that had a release date of 01-01-2006 would not have been selected in the "First public release" facet, which was looking for a value of 2006 and ignoring values that didn't look like that.

Data transformation is performed in OpenRefine by using the OpenRefine Expression Language, called GREL (the *G* is left over from OpenRefine's previous name, Google Refine). This language is used to create short lambda functions that transform the values in the cells based on simple rules. For example:

```
if(value.length() != 4, "invalid", value)
```

When this function is applied to the "First stable release" column, it preserves the values of the cells where the date is in a YYYY format, and marks all other columns as `invalid` (Figure 8-4).

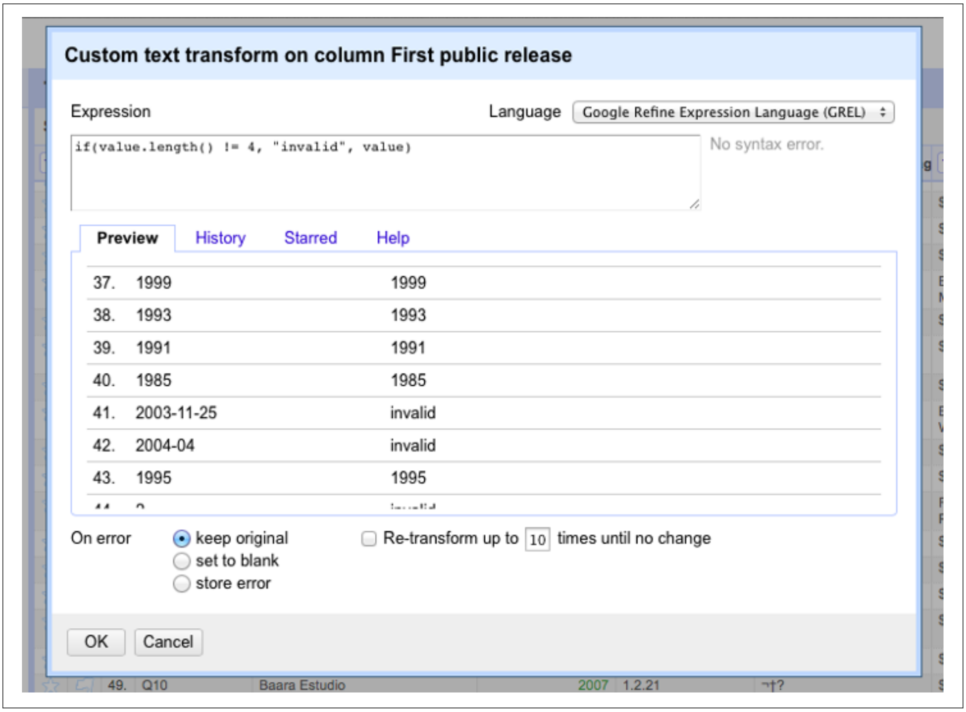


Figure 8-4. Inserting a GREL statement into a project (a preview display is shown below the statement)

Arbitrary GREL statements can be applied by clicking the down arrow next to any column's label and choosing Edit cells → Transform.

However, marking all less-than-ideal values as invalid, while making them easy to spot, doesn't do you much good. It'd be better to try to salvage information from the badly formatted values if possible. This can be done using GREL's `match` function:

```
value.match(".*([0-9]{4}).*").get(0)
```

This attempts to match the string value against the regular expression given. If the regular expression matches the string, an array is returned. Any substrings that match the "capture group" in the regular expression (demarcated by the parentheses in the expression, in this example, `[0-9]{4}`) are returned as array values.

This code, in effect, finds all instances of four decimals in a row and returns the first one. This is usually sufficient to extract years from text or badly formatted dates. It also has the benefit of returning `null` for nonexistent dates. (GREL does not throw a null pointer exception when performing operations on a null variable.)

Many other data transformations are possible with cell editing and GREL. A complete guide to the language can be found on OpenRefine's GitHub page.

CHAPTER 9
Reading and Writing Natural Languages

So far, the data you have worked with generally has been in the form of numbers or countable values. In most cases, you've simply stored the data without conducting any analysis after the fact. This chapter attempts to tackle the tricky subject of the English language.[1]

How does Google know what you're looking for when you type "cute kitten" into its Image Search? Because of the text that surrounds the cute kitten images. How does YouTube know to bring up a certain Monty Python sketch when you type "dead parrot" into its search bar? Because of the title and description text that accompanies each uploaded video.

In fact, even typing in terms such as "deceased bird monty python" immediately brings up the same "Dead Parrot" sketch, even though the page itself contains no mention of the words "deceased" or "bird." Google knows that a "hot dog" is a food and that a "boiling puppy" is an entirely different thing. How? It's all statistics!

Although you might not think that text analysis has anything to do with your project, understanding the concepts behind it can be extremely useful for all sorts of machine learning, as well as the more general ability to model real-world problems in probabilistic and algorithmic terms.

For instance, the Shazam music service can identify audio as containing a certain song recording, even if that audio contains ambient noise or distortion. Google is

1 Although many of the techniques described in this chapter can be applied to all or most languages, it's okay for now to focus on natural language processing in English only. Tools such as Python's Natural Language Toolkit, for example, focus on English. Fifty-six percent of the internet is still in English (with German following at a mere 6%, according to W3Techs). But who knows? English's hold on the majority of the internet will almost certainly change in the future, and further updates may be necessary in the next few years.

working on automatically captioning images based on nothing but the image itself.[2] By comparing known images of, say, hot dogs to other images of hot dogs, the search engine can gradually learn what a hot dog looks like and observe these patterns in additional images it is shown.

Summarizing Data

In Chapter 8, you looked at breaking up text content into n-grams, or sets of phrases that are *n* words in length. At a basic level, this can be used to determine which sets of words and phrases tend to be most commonly used in a section of text. In addition, it can be used to create natural-sounding data summaries by going back to the original text and extracting sentences around some of these most popular phrases.

One piece of sample text you'll be using to do this is the inauguration speech of the ninth president of the United States, William Henry Harrison. Harrison's presidency sets two records in the history of the office: one for the longest inauguration speech, and another for the shortest time in office, 32 days.

You'll use the full text of this speech as the source for many of the code samples in this chapter.

Slightly modifying the n-gram used to find code in Chapter 8, you can produce code that looks for sets of 2-grams and returns a `Counter` object with all 2-grams:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re
import string
from collections import Counter

def cleanSentence(sentence):
    sentence = sentence.split(' ')
    sentence = [word.strip(string.punctuation+string.whitespace)
        for word in sentence]
    sentence = [word for word in sentence if len(word) > 1
        or (word.lower() == 'a' or word.lower() == 'i')]
    return sentence

def cleanInput(content):
    content = content.upper()
    content = re.sub('\n', ' ', content)
    content = bytes(content, "UTF-8")
    content = content.decode("ascii", "ignore")
    sentences = content.split('. ')
    return [cleanSentence(sentence) for sentence in sentences]
```

2 Oriol Vinyals et al, "A Picture Is Worth a Thousand (Coherent) Words: Building a Natural Description of Images", Google Research Blog, November 17, 2014.

```
def getNgramsFromSentence(content, n):
    output = []
    for i in range(len(content)-n+1):
        output.append(content[i:i+n])
    return output

def getNgrams(content, n):
    content = cleanInput(content)
    ngrams = Counter()
    ngrams_list = []
    for sentence in content:
        newNgrams = [' '.join(ngram) for ngram in
            getNgramsFromSentence(sentence, 2)]
        ngrams_list.extend(newNgrams)
        ngrams.update(newNgrams)
    return(ngrams)


content = str(
      urlopen('http://pythonscraping.com/files/inaugurationSpeech.txt')
        .read(), 'utf-8')
ngrams = getNgrams(content, 2)
print(ngrams)
```

The output produces, in part:

```
Counter({'OF THE': 213, 'IN THE': 65, 'TO THE': 61, 'BY THE': 41,
'THE CONSTITUTION': 34, 'OF OUR': 29, 'TO BE': 26, 'THE PEOPLE': 24,
'FROM THE': 24, 'THAT THE': 23,...
```

Of these 2-grams, "the constitution" seems like a reasonably popular subject in the speech, but "of the," "in the," and "to the" don't seem especially noteworthy. How can you automatically get rid of unwanted words in an accurate way?

Fortunately, there are people out there who carefully study the differences between "interesting" words and "uninteresting" words, and their work can help us do just that. Mark Davies, a linguistics professor at Brigham Young University, maintains the Corpus of Contemporary American English, a collection of over 450 million words from the last decade or so of popular American publications.

The list of 5,000 most frequently found words is available for free, and fortunately, this is far more than enough to act as a basic filter to weed out the most common 2-grams. Just the first 100 words vastly improves the results, with the addition of an `isCommon` function:

```
def isCommon(ngram):
    commonWords = ['THE', 'BE', 'AND', 'OF', 'A', 'IN', 'TO', 'HAVE', 'IT', 'I',
        'THAT', 'FOR', 'YOU', 'HE', 'WITH', 'ON', 'DO', 'SAY', 'THIS', 'THEY',
        'IS', 'AN', 'AT', 'BUT', 'WE', 'HIS', 'FROM', 'THAT', 'NOT', 'BY',
        'SHE', 'OR', 'AS', 'WHAT', 'GO', 'THEIR', 'CAN', 'WHO', 'GET', 'IF',
        'WOULD', 'HER', 'ALL', 'MY', 'MAKE', 'ABOUT', 'KNOW', 'WILL', 'AS',
```

```
        'UP', 'ONE', 'TIME', 'HAS', 'BEEN', 'THERE', 'YEAR', 'SO', 'THINK',
        'WHEN', 'WHICH', 'THEM', 'SOME', 'ME', 'PEOPLE', 'TAKE', 'OUT', 'INTO',
        'JUST', 'SEE', 'HIM', 'YOUR', 'COME', 'COULD', 'NOW', 'THAN', 'LIKE',
        'OTHER', 'HOW', 'THEN', 'ITS', 'OUR', 'TWO', 'MORE', 'THESE', 'WANT',
        'WAY', 'LOOK', 'FIRST', 'ALSO', 'NEW', 'BECAUSE', 'DAY', 'MORE', 'USE',
        'NO', 'MAN', 'FIND', 'HERE', 'THING', 'GIVE', 'MANY', 'WELL']
    for word in ngram:
        if word in commonWords:
            return True
    return False
```

This produces the following 2-grams that were found more than twice in the text body:

```
Counter({'UNITED STATES': 10, 'EXECUTIVE DEPARTMENT': 4,
'GENERAL GOVERNMENT': 4, 'CALLED UPON': 3, 'CHIEF MAGISTRATE': 3,
'LEGISLATIVE BODY': 3, 'SAME CAUSES': 3, 'GOVERNMENT SHOULD': 3,
'WHOLE COUNTRY': 3,...
```

Appropriately enough, the first two items in the list are "United States" and "executive department," which you would expect for a presidential inauguration speech.

It's important to note that you are using a list of common words from relatively modern times to filter the results, which might not be appropriate given that the text was written in 1841. However, because you're using only the first 100 or so words on the list—which you can assume are more stable over time than, say, the last 100 words—and you appear to be getting satisfactory results, you can likely save yourself the effort of tracking down or creating a list of the most common words from 1841 (although such an effort might be interesting).

Now that some key topics have been extracted from the text, how does this help you write text summaries? One way is to search for the first sentence that contains each "popular" n-gram, the theory being that the first instance will yield a satisfactory overview of the body of the content. The first five most popular 2-grams yield these bullet points:

- The Constitution of the United States is the instrument containing this grant of power to the several departments composing the Government.
- Such a one was afforded by the executive department constituted by the Constitution.
- The General Government has seized upon none of the reserved rights of the States.
- Called from a retirement which I had supposed was to continue for the residue of my life to fill the chief executive office of this great and free nation, I appear before you, fellow-citizens, to take the oaths which the constitution prescribes as a necessary qualification for the performance of its duties; and in obedience to a custom coeval with our government and what I believe to be your expectations I

proceed to present to you a summary of the principles which will govern me in the discharge of the duties which I shall be called upon to perform.

- The presses in the necessary employment of the Government should never be used to "clear the guilty or to varnish crime."

Sure, it might not be published in CliffsNotes any time soon, but considering that the original document was 217 sentences in length, and the fourth sentence ("Called from a retirement...") condenses the main subject down fairly well, it's not too bad for a first pass.

With longer blocks of text, or more varied text, it may be worth looking at 3-grams or even 4-grams when retrieving the "most important" sentences of a passage. In this case, only one 3-gram is used multiple times and that is "exclusive metallic currency" —hardly a defining phrase for a presidential inauguration speech. With longer passages, using 3-grams may be appropriate.

Another approach is to look for sentences that contain the most popular n-grams. These will, of course, tend to be longer sentences, so if that becomes a problem, you can look for sentences with the highest percentage of words that are popular n-grams, or create a scoring metric of your own, combining several techniques.

Markov Models

You might have heard of Markov text generators. They've become popular for entertainment purposes, as in the "That can be my next tweet!" app, as well as their use for generating real-sounding spam emails to fool detection systems.

All of these text generators are based on the Markov model, which is often used to analyze large sets of random events, where one discrete event is followed by another discrete event with a certain probability.

For example, you might build a Markov model of a weather system, as illustrated in Figure 9-1.

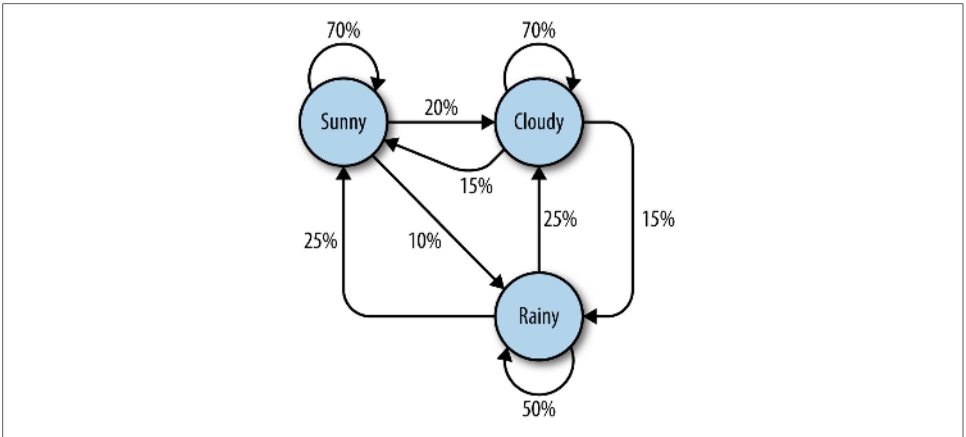


Figure 9-1. Markov model describing a theoretical weather system

In this model, each sunny day has a 70% chance of the following day also being sunny, with a 20% chance of the following day being cloudy with a mere 10% chance of rain. If the day is rainy, there is a 50% chance of rain the following day, a 25% chance of sun, and a 25% chance of clouds.

You might note several properties in this Markov model:

- All percentages leading away from any one node must add up to exactly 100%. No matter how complicated the system, there must always be a 100% chance that it can lead somewhere else in the next step.
- Although there are only three possibilities for the weather at any given time, you can use this model to generate an infinite list of weather states.
- Only the state of the current node you are on influences where you will go to next. If you're on the Sunny node, it doesn't matter if the preceding 100 days were sunny or rainy—the chances of sun the next day are exactly the same: 70%.
- It might be more difficult to reach some nodes than others. The math behind this is reasonably complicated, but it should be fairly easy to see that Rainy (with less than "100%" worth of arrows pointing toward it) is a much less likely state to reach in this system, at any given point in time, than Sunny or Cloudy.

Obviously, this is a simple system, and Markov models can grow arbitrarily large. Google's page-rank algorithm is based partly on a Markov model, with websites represented as nodes and inbound/outbound links represented as connections between nodes. The "likelihood" of landing on a particular node represents the relative popularity of the site. That is, if our weather system represented an extremely small internet, "rainy" would have a low page rank, while "cloudy" would have a high page rank.

With all of this in mind, let's bring it back down to a more concrete example: analyzing and writing text.

Again using the inauguration speech of William Henry Harrison analyzed in the previous example, you can write the following code that generates arbitrarily long Markov chains (with the chain length set to 100) based on the structure of its text:

```
from urllib.request import urlopen
from random import randint

def wordListSum(wordList):
    sum = 0
    for word, value in wordList.items():
        sum += value
    return sum

def retrieveRandomWord(wordList):
    randIndex = randint(1, wordListSum(wordList))
    for word, value in wordList.items():
        randIndex -= value
        if randIndex <= 0:
            return word

def buildWordDict(text):
    # Remove newlines and quotes
    text = text.replace('\n', ' ');
    text = text.replace('"', '');

    # Make sure punctuation marks are treated as their own "words,"
    # so that they will be included in the Markov chain
    punctuation = [',','.',';',':']
    for symbol in punctuation:
        text = text.replace(symbol, ' {} '.format(symbol));

    words = text.split(' ')
    # Filter out empty words
    words = [word for word in words if word != '']

    wordDict = {}
    for i in range(1, len(words)):
        if words[i-1] not in wordDict:
                # Create a new dictionary for this word
            wordDict[words[i-1]] = {}
        if words[i] not in wordDict[words[i-1]]:
            wordDict[words[i-1]][words[i]] = 0
        wordDict[words[i-1]][words[i]] += 1
    return wordDict

text = str(urlopen('http://pythonscraping.com/files/inaugurationSpeech.txt')
          .read(), 'utf-8')
wordDict = buildWordDict(text)
```

```
#Generate a Markov chain of length 100
length = 100
chain = ['I']
for i in range(0, length):
    newWord = retrieveRandomWord(wordDict[chain[-1]])
    chain.append(newWord)

print(' '.join(chain))
```

The output of this code changes every time it is run, but here's an example of the uncannily nonsensical text it will generate:

```
I sincerely believe in Chief Magistrate to make all necessary sacrifices and
oppression of the remedies which we may have occurred to me in the arrangement
and disbursement of the democratic claims them , consolatory to have been best
political power in fervently commending every other addition of legislation , by
the interests which violate that the Government would compare our aboriginal
neighbors the people to its accomplishment . The latter also susceptible of the
Constitution not much mischief , disputes have left to betray . The maxim which
may sometimes be an impartial and to prevent the adoption or
```

So what's going on in the code?

The function `buildWordDict` takes in the string of text, which was retrieved from the internet. It then does some cleaning and formatting, removing quotes and putting spaces around other punctuation so it is effectively treated as a separate word. After this, it builds a two-dimensional dictionary—a dictionary of dictionaries—that has the following form:

```
{word_a : {word_b : 2, word_c : 1, word_d : 1},
 word_e : {word_b : 5, word_d : 2},...}
```

In this example dictionary, "word_a" was found four times, two instances of which were followed by "word_b," one instance followed by "word_c," and one instance followed by "word_d." "Word_e" was followed seven times, five times by "word_b" and twice by "word_d."

If we were to draw a node model of this result, the node representing `word_a` would have a 50% arrow pointing toward "word_b" (which followed it two out of four times), a 25% arrow pointing toward "word_c," and a 25% arrow pointing toward "word_d."

After this dictionary is built up, it can be used as a lookup table to see where to go next, no matter which word in the text you happen to be on.[3] Using the sample dictio-

3 The exception is the last word in the text, because nothing follows the last word. In our example text, the last word is a period (.), which is convenient because it has 215 other occurrences in the text and so does not represent a dead-end. However, in real-world implementations of the Markov generator, the last word of the text might be something you need to account for.

nary of dictionaries, you might currently be on "word_e," which means that you'll pass the dictionary `{word_b : 5, word_d: 2}` to the `retrieveRandomWord` function. This function in turn retrieves a random word from the dictionary, weighted by the number of times it occurs.

By starting with a random starting word (in this case, the ubiquitous "I"), you can traverse through the Markov chain easily, generating as many words as you like.

These Markov chains tend to improve in their "realism" as more text is collected, especially from sources with similar writing styles. Although this example used 2-grams to create the chain (where the previous word predicts the next word) 3-grams or higher-order n-grams can be used, where two or more words predict the next word.

Although entertaining, and a great use for megabytes of text that you might have accumulated during web scraping, applications like these can make it difficult to see the practical side of Markov chains. As mentioned earlier in this section, Markov chains model how websites link from one page to the next. Large collections of these links as pointers can form weblike graphs that are useful to store, track, and analyze. In this way, Markov chains form the foundation for both how to think about web crawling, and how your web crawlers can think.

Six Degrees of Wikipedia: Conclusion

In Chapter 3, you created a scraper that collects links from one Wikipedia article to the next, starting with the article on Kevin Bacon, and in Chapter 6, stored those links in a database. Why am I bringing it up again? Because it turns out the problem of choosing a path of links that starts on one page and ends up on the target page (i.e., finding a string of pages between *https://en.wikipedia.org/wiki/Kevin_Bacon* and *https://en.wikipedia.org/wiki/Eric_Idle*) is the same as finding a Markov chain where both the first word and last word are defined.

These sorts of problems are *directed graph* problems, where A → B does not necessarily mean that B → A. The word "football" might often be followed by the word "player," but you'll find that the word "player" is much less often followed by the word "football." Although Kevin Bacon's Wikipedia article links to the article on his home city, Philadelphia, the article on Philadelphia does not reciprocate by linking back to him.

In contrast, the original Six Degrees of Kevin Bacon game is an *undirected graph* problem. If Kevin Bacon starred in *Flatliners* with Julia Roberts, then Julia Roberts necessarily starred in *Flatliners* with Kevin Bacon, so the relationship goes both ways (it has no "direction"). Undirected graph problems tend to be less common in computer science than directed graph problems, and both are computationally difficult to solve.

Although much work has been done on these sorts of problems and multitudes of variations on them, one of the best and most common ways to find shortest paths in a directed graph—and thus find paths between the Wikipedia article on Kevin Bacon and all other Wikipedia articles—is through a breadth-first search.

A *breadth-first search* is performed by first searching all links that link directly to the starting page. If those links do not contain the target page (the page you are searching for), then a second level of links—pages that are linked by a page that is linked by the starting page—is searched. This process continues until either the depth limit (6 in this case) is reached or the target page is found.

A complete solution to the breadth-first search, using a table of links as described in Chapter 6, is as follows:

```
import pymysql

conn = pymysql.connect(host='127.0.0.1', unix_socket='/tmp/mysql.sock',
    user='', passwd='', db='mysql', charset='utf8')
cur = conn.cursor()
cur.execute('USE wikipedia')

def getUrl(pageId):
    cur.execute('SELECT url FROM pages WHERE id = %s', (int(pageId)))
    return cur.fetchone()[0]

def getLinks(fromPageId):
    cur.execute('SELECT toPageId FROM links WHERE fromPageId = %s',
        (int(fromPageId)))
    if cur.rowcount == 0:
        return []
    return [x[0] for x in cur.fetchall()]

def searchBreadth(targetPageId, paths=[[1]]):
    newPaths = []
    for path in paths:
        links = getLinks(path[-1])
        for link in links:
            if link == targetPageId:
                return path + [link]
            else:
                newPaths.append(path+[link])
    return searchBreadth(targetPageId, newPaths)

nodes = getLinks(1)
targetPageId = 28624
pageIds = searchBreadth(targetPageId)
for pageId in pageIds:
    print(getUrl(pageId))
```

`getUrl` is a helper function that retrieves URLs from the database given a page ID. Similarly, `getLinks` takes a `fromPageId` representing the integer ID for the current page, and fetches a list of all integer IDs for pages it links to.

The main function, `searchBreadth`, works recursively to construct a list of all possible paths from the search page and stops when it finds a path that has reached the target page:

- It starts with a single path, `[1]`, representing a path in which the user stays on the target page with the ID 1 (Kevin Bacon) and follows no links.
- For each path in the list of paths (in the first pass, there is only one path, so this step is brief), it gets all of the links that link out from the page represented by the last page in the path.
- For each of these outbound links, it checks whether they match the `targetPageId`. If there's a match, that path is returned.
- If there's no match, a new path is added to a new list of (now longer) paths, consisting of the old path + the new outbound page link.
- If the `targetPageId` is not found at this level at all, a recursion occurs and `searchBreadth` is called with the same `targetPageId` and a new, longer, list of paths.

After the list of page IDs containing a path between the two pages is found, each ID is resolved to its actual URL and printed.

The output for searching for a link between the page on Kevin Bacon (page ID 1 in this database) and the page on Eric Idle (page ID 28624 in this database) is as follows:

```
/wiki/Kevin_Bacon
/wiki/Primetime_Emmy_Award_for_Outstanding_Lead_Actor_in_a_
Miniseries_or_a_Movie
/wiki/Gary_Gilmore
/wiki/Eric_Idle
```

This translates into the relationship of links: Kevin Bacon → Primetime Emmy Award → Gary Gilmore → Eric Idle.

In addition to solving Six Degree problems and modeling which words tend to follow which other words in sentences, directed and undirected graphs can be used to model a variety of situations encountered in web scraping. Which websites link to which other websites? Which research papers cite which other research papers? Which products tend to be shown with which other products on a retail site? What is the strength of this link? Is the link reciprocal?

Recognizing these fundamental types of relationships can be extremely helpful for making models, visualizations, and predictions based on scraped data.

Natural Language Toolkit

So far, this chapter has focused primarily on the statistical analysis of words in bodies of text. Which words are most popular? Which words are unusual? Which words are likely to come after which other words? How are they grouped together? What you are missing is understanding, to the extent that you can, what the words represent.

The *Natural Language Toolkit* (NLTK) is a suite of Python libraries designed to identify and tag parts of speech found in natural English text. Its development began in 2000, and over the past 15 years, dozens of developers around the world have contributed to the project. Although the functionality it provides is tremendous (entire books are devoted to NLTK), this section focuses on just a few of its uses.

Installation and Setup

The `nltk` module can be installed in the same way as other Python modules, either by downloading the package through the NLTK website directly or by using any number of third-party installers with the keyword "nltk." For complete installation instructions, see the NLTK website.

After installing the module, it's a good idea to download its preset text repositories so you can try the features more easily. Type this on the Python command line:

```
>>> import nltk
>>> nltk.download()
```

This opens the NLTK Downloader (Figure 9-2).

I recommend installing all of the available packages when first trying out the NLTK corpus. You can easily uninstall packages at any time.

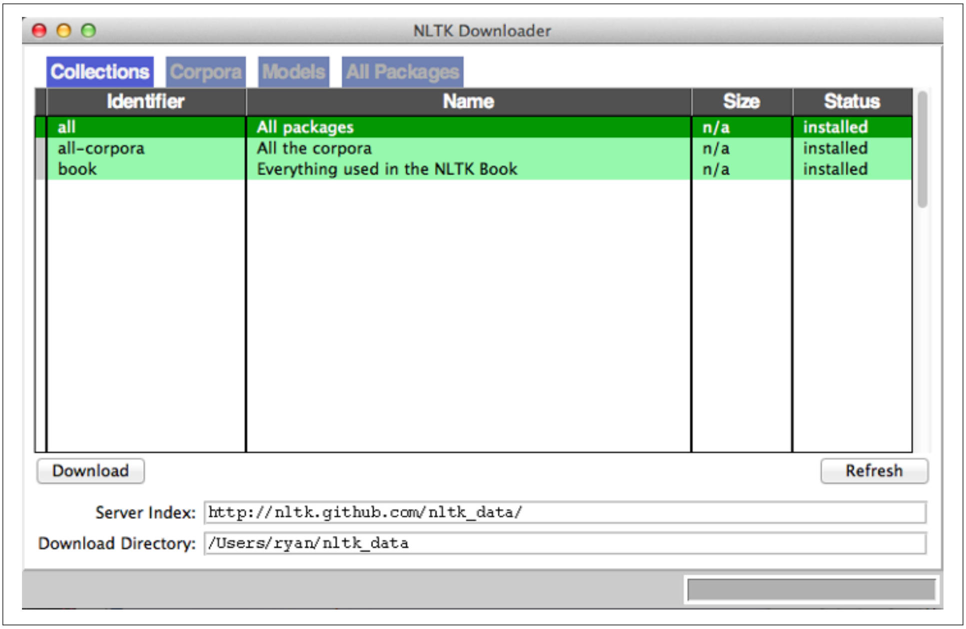


Figure 9-2. The NLTK Downloader lets you browse and download optional packages and text libraries associated with the nltk module

Statistical Analysis with NLTK

NLTK is great for generating statistical information about word counts, word frequency, and word diversity in sections of text. If all you need is a relatively straightforward calculation (e.g., the number of unique words used in a section of text), importing `nltk` might be overkill—it's a large module. However, if you need to do relatively extensive analysis of a text, you have functions at your fingertips that will give you just about any metric you want.

Analysis with NLTK always starts with the `Text` object. `Text` objects can be created from simple Python strings in the following way:

```
from nltk import word_tokenize
from nltk import Text

tokens = word_tokenize('Here is some not very interesting text')
text = Text(tokens)
```

The input for the `word_tokenize` function can be any Python text string. If you don't have any long strings handy but still want to play around with the features, NLTK has quite a few books already built into the library, which can be accessed using the `import` function:

```
from nltk.book import *
```

This loads the nine books:

```
*** Introductory Examples for the NLTK Book ***
Loading text1, ..., text9 and sent1, ..., sent9
Type the name of the text or sentence to view it.
Type: 'texts()' or 'sents()' to list the materials.
text1: Moby Dick by Herman Melville 1851
text2: Sense and Sensibility by Jane Austen 1811
text3: The Book of Genesis
text4: Inaugural Address Corpus
text5: Chat Corpus
text6: Monty Python and the Holy Grail
text7: Wall Street Journal
text8: Personals Corpus
text9: The Man Who Was Thursday by G . K . Chesterton 1908
```

You will be working with `text6`, "Monty Python and the Holy Grail" (the screenplay for the 1975 movie), in all of the following examples.

Text objects can be manipulated much like normal Python arrays, as if they were an array containing words of the text. Using this property, you can count the number of unique words in a text and compare it against the total number of words (remember that a Python `set` holds only unique values):

```
>>> len(text6)/len(set(text6))
7.833333333333333
```

The preceding shows that each word in the script was used about eight times on average. You can also put the text into a frequency distribution object to determine some of the most common words and the frequencies for various words:

```
>>> from nltk import FreqDist
>>> fdist = FreqDist(text6)
>>> fdist.most_common(10)
[(':', 1197), ('.', 816), ('!', 801), (',', 731), ("'", 421), ('[', 3
19), (']', 312), ('the', 299), ('I', 255), ('ARTHUR', 225)]
>>> fdist["Grail"]
34
```

Because this is a screenplay, some artifacts of how it is written can pop up. For instance, "ARTHUR" in all caps crops up frequently because it appears before each of King Arthur's lines in the script. In addition, a colon (:) appears before every single line, acting as a separator between the name of the character and the character's line. Using this fact, we can see that there are 1,197 lines in the movie!

What we have called 2-grams in previous chapters, NLTK refers to as *bigrams* (from time to time, you might also hear 3-grams referred to as *trigrams*, but I prefer 2-gram and 3-gram rather than bigram or trigram). You can create, search, and list 2-grams extremely easily:

```
>>> from nltk import bigrams
>>> bigrams = bigrams(text6)
>>> bigramsDist = FreqDist(bigrams)
>>> bigramsDist[('Sir', 'Robin')]
18
```

To search for the 2-grams "Sir Robin," you need to break it into the tuple ("Sir", "Robin"), to match the way the 2-grams are represented in the frequency distribution. There is also a `trigrams` module that works in the exact same way. For the general case, you can also import the `ngrams` module:

```
>>> from nltk import ngrams
>>> fourgrams = ngrams(text6, 4)
>>> fourgramsDist = FreqDist(fourgrams)
>>> fourgramsDist[('father', 'smelt', 'of', 'elderberries')]
1
```

Here, the `ngrams` function is called to break a text object into n-grams of any size, governed by the second parameter. In this case, you're breaking the text into 4-grams. Then, you can demonstrate that the phrase "father smelt of elderberries" occurs in the screenplay exactly once.

Frequency distributions, text objects, and n-grams also can be iterated through and operated on in a loop. The following prints out all 4-grams that begin with the word "coconut," for instance:

```
from nltk.book import *
from nltk import ngrams
fourgrams = ngrams(text6, 4)
for fourgram in fourgrams:
    if fourgram[0] == 'coconut':
        print(fourgram)
```

The NLTK library has a vast array of tools and objects designed to organize, count, sort, and measure large swaths of text. Although we've barely scratched the surface of their uses, most of these tools are well designed and operate rather intuitively for someone familiar with Python.

Lexicographical Analysis with NLTK

So far, you've compared and categorized all the words you've encountered based only on the value they represent by themselves. There is no differentiation between homonyms or the context in which the words are used.

Although some people might be tempted to dismiss homonyms as rarely problematic, you might be surprised at how frequently they crop up. Most native English speakers probably don't often register that a word is a homonym, much less consider that it might be confused for another word in a different context.

"He was objective in achieving his objective of writing an objective philosophy, primarily using verbs in the objective case" is easy for humans to parse but might make a web scraper think the same word is being used four times and cause it to simply discard all the information about the meaning behind each word.

In addition to sussing out parts of speech, being able to distinguish a word being used in one way versus another might be useful. For example, you might want to look for company names made up of common English words, or analyze someone's opinions about a company. "ACME Products is good" and "ACME Products is not bad" can have the same basic meaning, even if one sentence uses "good" and the other uses "bad."

Penn Treebank's Tags

NLTK uses by default a popular system of tagging parts of speech developed by the University of Pennsylvania's Penn Treebank Project. Although some of the tags make sense (e.g., CC is a coordinating conjunction), others can be confusing (e.g., RP is a particle). Use the following as a reference for the tags referred to in this section:

CC	Coordinating conjunction
CD	Cardinal number
DT	Determiner
EX	Existential "there"
FW	Foreign word
IN	Preposition, subordinating conjunction
JJ	Adjective
JJR	Adjective, comparative
JJS	Adjective, superlative
LS	List item marker
MD	Modal
NN	Noun, singular or mass
NNS	Noun, plural
NNP	Proper noun, singular
NNPS	Proper noun, plural
PDT	Predeterminer
POS	Possessive ending
PRP	Personal pronoun
PRP$	Possessive pronoun
RB	Adverb
RBR	Adverb, comparative

RBS	Adverb, superlative
RP	Particle
SYM	Symbol
TO	"to"
UH	Interjection
VB	Verb, base form
VBD	Verb, past tense
VBG	Verb, gerund or present participle
VBN	Verb, past participle
VBP	Verb, non-third-person singular present
VBZ	Verb, third person singular present
WDT	wh-determiner
WP	Wh-pronoun
WP$	Possessive wh-pronoun
WRB	Wh-adverb

In addition to measuring language, NLTK can assist in finding meaning in the words based on context and its own sizable dictionaries. At a basic level, NLTK can identify parts of speech:

```
>>> from nltk.book import *
>>> from nltk import word_tokenize
>>> text = word_tokenize('Strange women lying in ponds distributing swords'\
'is no basis for a system of government.')
>>> from nltk import pos_tag
>>> pos_tag(text)
[('Strange', 'NNP'), ('women', 'NNS'), ('lying', 'VBG'), ('in', 'IN')
, ('ponds', 'NNS'), ('distributing', 'VBG'), ('swords', 'NNS'), ('is'
, 'VBZ'), ('no', 'DT'), ('basis', 'NN'), ('for', 'IN'), ('a', 'DT'),
('system', 'NN'), ('of', 'IN'), ('government', 'NN'), ('.', '.')]
```

Each word is separated into a *tuple* containing the word and a tag identifying the part of speech (see the preceding sidebar for more information about these tags). Although this might seem like a straightforward lookup, the complexity needed to perform the task correctly becomes apparent with the following example:

```
>>> text = word_tokenize('The dust was thick so he had to dust')
>>> pos_tag(text)
[('The', 'DT'), ('dust', 'NN'), ('was', 'VBD'), ('thick', 'JJ'), ('so
', 'RB'), ('he', 'PRP'), ('had', 'VBD'), ('to', 'TO'), ('dust', 'VB')]
```

Notice that the word "dust" is used twice in the sentence: once as a noun, and again as a verb. NLTK identifies both usages correctly, based on their context in the sentence. NLTK identifies parts of speech by using a context-free grammar defined by the

English language. *Context-free grammars* are sets of rules that define which things are allowed to follow which other things in ordered lists. In this case, they define which parts of speech are allowed to follow which other parts of speech. Whenever an ambiguous word such as "dust" is encountered, the rules of the context-free grammar are consulted, and an appropriate part of speech that follows the rules is selected.

Machine Learning and Machine Training

You can have NLTK generate brand-new context-free grammars when training it, for example, on a foreign language. If you tag large sections of text by hand in the language by using the appropriate Penn Treebank Tags, you can feed them back into NLTK and train it to properly tag other text it might encounter. This type of training is a necessary component of any machine-learning activity that you will revisit in Chapter 14, when training scrapers to recognize CAPTCHA characters.

What's the point of knowing whether a word is a verb or a noun in a given context? It might be neat in a computer science research lab, but how does it help with web scraping?

A common problem in web scraping deals with search. You might be scraping text off a site and want to be able to search it for instances of the word "google," but only when it's being used as a verb, not a proper noun. Or you might be looking only for instances of the company Google and don't want to rely on people's correct use of capitalization in order to find those instances. Here, the `pos_tag` function can be extremely useful:

```
from nltk import word_tokenize, sent_tokenize, pos_tag
sentences = sent_tokenize('Google is one of the best companies in the world.'\
' I constantly google myself to see what I\'m up to.')
nouns = ['NN', 'NNS', 'NNP', 'NNPS']

for sentence in sentences:
    if 'google' in sentence.lower():
        taggedWords = pos_tag(word_tokenize(sentence))
            for word in taggedWords:
                if word[0].lower() == 'google' and word[1] in nouns:
                    print(sentence)
```

This prints only sentences that contain the word "google" (or "Google") as some sort of a noun, not a verb. Of course, you could be more specific and demand that only instances of Google tagged with "NNP" (a proper noun) are printed, but even NLTK makes mistakes at times, and it can be good to leave yourself a little wiggle room, depending on the application.

Much of the ambiguity of natural language can be resolved using NLTK's `pos_tag` function. By searching text not just for instances of your target word or phrase but

instances of your target word or phrase *plus* its tag, you can greatly increase the accuracy and effectiveness of your scraper's searches.

Additional Resources

Processing, analyzing, and understanding natural language by machine is one of the most difficult tasks in computer science, and countless volumes and research papers have been written on the subject. I hope that the coverage here will inspire you to think beyond conventional web scraping, or at least give some initial direction about where to begin when undertaking a project that requires natural language analysis.

Many excellent resources are available on introductory language processing and Python's Natural Language Toolkit. In particular, Steven Bird, Ewan Klein, and Edward Loper's book *Natural Language Processing with Python* (O'Reilly) presents both a comprehensive and introductory approach to the topic.

In addition, James Pustejovsky and Amber Stubbs' *Natural Language Annotations for Machine Learning* (O'Reilly) provides a slightly more advanced theoretical guide. You'll need knowledge of Python to implement the lessons; the topics covered work perfectly with Python's Natural Language Toolkit.

CHAPTER 10
Crawling Through Forms and Logins

One of the first questions that comes up when you start to move beyond the basics of web scraping is: "How do I access information behind a login screen?" The web is increasingly moving toward interaction, social media, and user-generated content. Forms and logins are an integral part of these types of sites and almost impossible to avoid. Fortunately, they are also relatively easy to deal with.

Until this point, most of our interactions with web servers in our example scrapers have consisted of using HTTP `GET` to request information. This chapter focuses on the `POST` method, which pushes information to a web server for storage and analysis.

Forms basically give users a way to submit a `POST` request that the web server can understand and use. Just as link tags on a website help users format `GET` requests, HTML forms help them format `POST` requests. Of course, with a little bit of coding, it is possible to create these requests ourselves and submit them with a scraper.

Python Requests Library

Although it's possible to navigate web forms by using only the Python core libraries, sometimes a little syntactic sugar makes life a lot sweeter. When you start to do more than a basic `GET` request with `urllib`, looking outside the Python core libraries can be helpful.

The Requests library is excellent at handling complicated HTTP requests, cookies, headers, and much more. Here's what Requests creator Kenneth Reitz has to say about Python's core tools:

> Python's standard `urllib2` module provides most of the HTTP capabilities you need, but the API is thoroughly broken. It was built for a different time—and a different web. It requires an enormous amount of work (even method overrides) to perform the simplest of tasks.
>
> Things shouldn't be this way. Not in Python.

As with any Python library, the *Requests* library can be installed with any third-party Python library manager, such as pip, or by downloading and installing the source file.

Submitting a Basic Form

Most web forms consist of a few HTML fields, a submit button, and an action page, where the actual form processing is done. The HTML fields usually consist of text but might also contain a file upload or other nontext content.

Most popular websites block access to their login forms in their *robots.txt* file (Chapter 18 discusses the legality of scraping such forms), so to play it safe I've constructed a series of different types of forms and logins at *pythonscraping.com* that you can run your web scrapers against. *http://pythonscraping.com/pages/files/form.html* is the location of the most basic of these forms.

The entirety of the form is as follows:

```
<form method="post" action="processing.php">
First name: <input type="text" name="firstname"><br>
Last name: <input type="text" name="lastname"><br>
<input type="submit" value="Submit">
</form>
```

A couple of things to notice here: first, the names of the two input fields are `firstname` and `lastname`. This is important. The names of these fields determine the names of the variable parameters that will be `POST`ed to the server when the form is submitted. If you want to mimic the action that the form will take when `POST`ing your own data, you need to make sure that your variable names match up.

The second thing to note is that the action of the form is at *processing.php* (the absolute path is *http://pythonscraping.com/files/processing.php*). Any `POST` requests to the form should be made on *this* page, not on the page that the form itself resides. Remember: the purpose of HTML forms is only to help website visitors format proper requests to send to the page that does the real action. Unless you are doing research to format the request itself, you don't need to bother much with the page that the form can be found on.

Submitting a form with the *Requests* library can be done in four lines, including the import and the instruction to print the content (yes, it's that easy):

```
import requests

params = {'firstname': 'Ryan', 'lastname': 'Mitchell'}
r = requests.post("http://pythonscraping.com/pages/processing.php", data=params)
print(r.text)
```

After the form is submitted, the script should return with the page's content:

```
Hello there, Ryan Mitchell!
```

This script can be applied to many simple forms encountered on the internet. The form to sign up for the O'Reilly Media newsletter, for example, looks like this:

```
<form action="http://post.oreilly.com/client/o/oreilly/forms/
              quicksignup.cgi" id="example_form2" method="POST">
    <input name="client_token" type="hidden" value="oreilly" />
    <input name="subscribe" type="hidden" value="optin" />
    <input name="success_url" type="hidden" value="http://oreilly.com/store/
             newsletter-thankyou.html" />
    <input name="error_url" type="hidden" value="http://oreilly.com/store/
             newsletter-signup-error.html" />
    <input name="topic_or_dod" type="hidden" value="1" />
    <input name="source" type="hidden" value="orm-home-t1-dotd" />
    <fieldset>
        <input class="email_address long" maxlength="200" name=
                     "email_addr" size="25" type="text" value=
                     "Enter your email here" />
        <button alt="Join" class="skinny" name="submit" onclick=
                       "return addClickTracking('orm','ebook','rightrail','dod'
                                                   );" value="submit">Join</button>
    </fieldset>
</form>
```

Although it can look daunting at first, remember that in most cases (we'll cover the exceptions later), you're looking for only two things:

- The name of the field (or fields) you want to submit with the data (in this case, the name is `email_addr`)
- The action attribute of the form itself; that is, the page that the form posts to (in this case, *http://post.oreilly.com/client/o/oreilly/forms/quicksignup.cgi*)

Just add in the required information and run it:

```
import requests
params = {'email_addr': 'ryan.e.mitchell@gmail.com'}
r = requests.post("http://post.oreilly.com/client/o/oreilly/forms/quicksignup.cgi",
                   data=params)
print(r.text)
```

In this case, the website returned is another form to fill out, before you can make it onto O'Reilly's mailing list, but the same concept could be applied to that form as

well. However, I request that you use your powers for good, and not spam the publisher with invalid signups, if you want to try this at home.

Radio Buttons, Checkboxes, and Other Inputs

Obviously, not all web forms are a collection of text fields followed by a submit button. Standard HTML contains a wide variety of possible form input fields: radio buttons, checkboxes, and select boxes, to name a few. HTML5 adds sliders (range input fields), email, dates, and more. With custom JavaScript fields, the possibilities are endless, with color pickers, calendars, and whatever else the developers come up with next.

Regardless of the seeming complexity of any sort of form field, you need to worry about only two things: the name of the element and its value. The element's name can be easily determined by looking at the source code and finding the `name` attribute. The value can sometimes be trickier, as it might be populated by JavaScript immediately before form submission. Color pickers, as an example of a fairly exotic form field, will likely have a value of something like `#F03030`.

If you're unsure of the format of an input field's value, you can use various tools to track the `GET` and `POST` requests your browser is sending to and from sites. The best and perhaps most obvious way to track `GET` requests, as mentioned before, is to look at the URL of a site. If the URL is something like

```
http://domainname.com?thing1=foo&thing2=bar
```

you know that this corresponds to a form of this type

```
<form method="GET" action="someProcessor.php">
<input type="someCrazyInputType" name="thing1" value="foo" />
<input type="anotherCrazyInputType" name="thing2" value="bar" />
<input type="submit" value="Submit" />
</form>
```

which corresponds to the Python parameter object

```
{'thing1':'foo', 'thing2':'bar'}
```

If you're stuck with a complicated-looking `POST` form, and you want to see exactly which parameters your browser is sending to the server, the easiest way is to use your browser's inspector or developer tool to view them (see Figure 10-1).

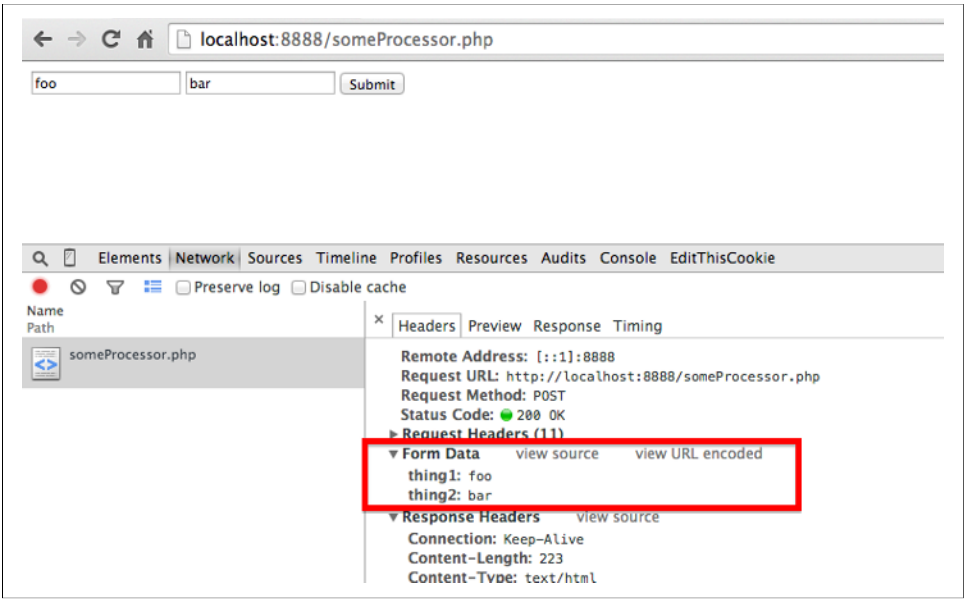


Figure 10-1. The Form Data section, highlighted in a box, shows the POST parameters "thing1" and "thing2" with their values "foo" and "bar"

The Chrome developer tool can be accessed via the menu by selecting View → Developer → Developer Tools. It provides a list of all queries that your browser produces while interacting with the current website and can be a good way to view the composition of these queries in detail.

Submitting Files and Images

Although file uploads are common on the internet, file uploads are not something often used in web scraping. It is possible, however, that you might want to write a test for your own site that involves a file upload. At any rate, it's a useful thing to know how to do.

There is a practice file upload form at *http://pythonscraping/files/form2.html*. The form on the page has the following markup:

```
<form action="processing2.php" method="post" enctype="multipart/form-data">
  Submit a jpg, png, or gif: <input type="file" name="uploadFile"><br>
  <input type="submit" value="Upload File">
</form>
```

Except for the `<input>` tag having the type attribute `file`, it looks essentially the same as the text-based forms used in the previous examples. Fortunately, the way the forms are used by the Python Requests library is also similar:

```
import requests

files = {'uploadFile': open('files/python.png', 'rb')}
r = requests.post('http://pythonscraping.com/pages/processing2.php',
                  files=files)
print(r.text)
```

Note that in lieu of a simple string, the value submitted to the form field (with the name `uploadFile`) is now a Python File object, as returned by the `open` function. In this example, you're submitting an image file, stored on your local machine, at the path *../files/Python-logo.png*, relative to where the Python script is being run from.

Yes, it's really that easy!

Handling Logins and Cookies

So far, we've mostly discussed forms that allow you to submit information to a site or let you view needed information on the page immediately after the form. How is this different from a login form, which lets you exist in a permanent "logged-in" state throughout your visit to the site?

Most modern websites use cookies to keep track of who is logged in and who is not. After a site authenticates your login credentials, it stores them in your browser's cookie, which usually contains a server-generated token, time-out, and tracking information. The site then uses this cookie as a sort of proof of authentication, which is shown to each page you visit during your time on the site. Before the widespread use of cookies in the mid-90s, keeping users securely authenticated and tracking them was a huge problem for websites.

Although cookies are a great solution for web developers, they can be problematic for web scrapers. You can submit a login form all day long, but if you don't keep track of the cookie the form sends back to you afterward, the next page you visit will act as though you've never logged in at all.

I've created a simple login form at *http://pythonscraping.com/pages/cookies/login.html* (the username can be anything, but the password must be "password"). This form is processed at *http://pythonscraping.com/pages/cookies/welcome.php*, which contains a link to the main page, *http://pythonscraping.com/pages/cookies/profile.php*.

If you attempt to access the welcome page or the profile page without logging in first, you'll get an error message and instructions to log in first before continuing. On the profile page, a check is done on your browser's cookies to see whether its cookie was set on the login page.

Keeping track of cookies is easy with the *Requests* library:

```
import requests
```

```python
params = {'username': 'Ryan', 'password': 'password'}
r = requests.post('http://pythonscraping.com/pages/cookies/welcome.php', params)
print('Cookie is set to:')
print(r.cookies.get_dict())
print('Going to profile page...')
r = requests.get('http://pythonscraping.com/pages/cookies/profile.php',
                 cookies=r.cookies)
print(r.text)
```

Here you're sending the login parameters to the welcome page, which acts as the processor for the login form. You retrieve the cookies from the results of the last request, print the result for verification, and then send them to the profile page by setting the `cookies` argument.

This works well for simple situations, but what if you're dealing with a more complicated site that frequently modifies cookies without warning, or if you'd rather not even think about the cookies to begin with? The Requests `session` function works perfectly in this case:

```python
import requests

session = requests.Session()

params = {'username': 'username', 'password': 'password'}
s = session.post('http://pythonscraping.com/pages/cookies/welcome.php', params)
print('Cookie is set to:')
print(s.cookies.get_dict())
print('Going to profile page...')
s = session.get('http://pythonscraping.com/pages/cookies/profile.php')
print(s.text)
```

In this case, the session object (retrieved by calling `requests.Session()`) keeps track of session information, such as cookies, headers, and even information about protocols you might be running on top of HTTP, such as HTTPAdapters.

Requests is a fantastic library, second perhaps only to Selenium (covered in Chapter 11) in the completeness of what it handles without programmers having to think about it or write the code themselves. Although it might be tempting to sit back and let the library do all the work, it's extremely important to always be aware of what the cookies look like and what they are controlling when writing web scrapers. It could save many hours of painful debugging or figuring out why a website is behaving strangely!

HTTP Basic Access Authentication

Before the advent of cookies, one popular way to handle logins was with HTTP *basic access authentication*. You still see it from time to time, especially on high-security or corporate sites, and with some APIs. I've created a page at *http://pythonscraping.com/pages/auth/login.php* that has this type of authentication (Figure 10-2).

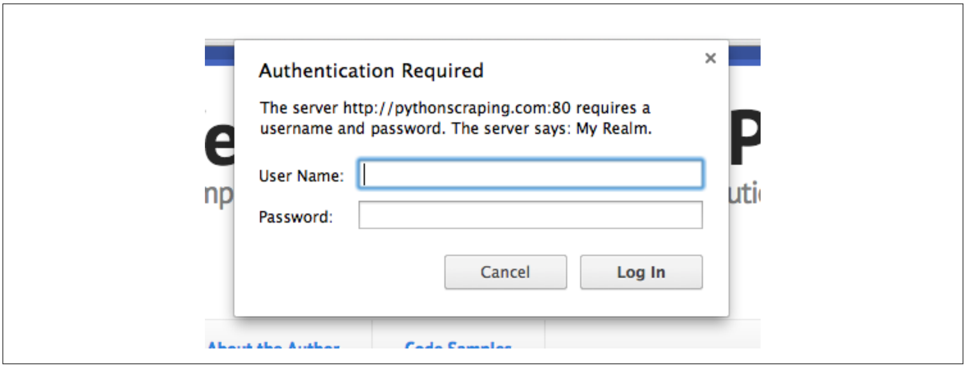


Figure 10-2. The user must provide a username and password to get to the page protected by basic access authentication

As usual with these examples, you can log in with any username, but the password must be "password."

The Requests package contains an `auth` module specifically designed to handle HTTP authentication:

```
import requests
from requests.auth import AuthBase
from requests.auth import HTTPBasicAuth

auth = HTTPBasicAuth('ryan', 'password')
r = requests.post(url='http://pythonscraping.com/pages/auth/login.php', auth=
                  auth)
print(r.text)
```

Although this appears to be a normal `POST` request, an `HTTPBasicAuth` object is passed as the `auth` argument in the request. The resulting text will be the page protected by the username and password (or an Access Denied page, if the request failed).

Other Form Problems

Web forms are a hot point of entry for malicious bots. You don't want bots creating user accounts, taking up valuable server processing time, or submitting spam comments on a blog. For this reason, security features often are incorporated into HTML forms on modern websites that might not be immediately apparent.

For help with CAPTCHAs, check out Chapter 13, which covers image processing and text recognition in Python.

If you encounter a mysterious error, or the server is rejecting your form submission for an unknown reason, check out Chapter 14, which covers honeypots, hidden fields, and other security measures that websites take to protect their forms.

CHAPTER 11

Scraping JavaScript

Client-side scripting languages are languages that are run in the browser itself, rather than on a web server. The success of a client-side language depends on your browser's ability to interpret and execute the language correctly. (This is why it's so easy to disable JavaScript in your browser.)

Partly because of the difficulty of getting every browser manufacturer to agree on a standard, there are far fewer client-side languages than there are server-side languages. This is a good thing when it comes to web scraping: the fewer languages there are to deal with, the better.

For the most part, you'll frequently encounter only two languages online: ActionScript (which is used by Flash applications) and JavaScript. ActionScript is used far less frequently today than it was 10 years ago, and is often used to stream multimedia files, as a platform for online games, or to display intro pages for websites that haven't gotten the hint that no one wants to watch an intro page. At any rate, because there isn't much demand for scraping Flash pages, this chapter instead focuses on the client-side language that's ubiquitous in modern web pages: JavaScript.

JavaScript is, by far, the most common and most well-supported client-side scripting language on the web today. It can be used to collect information for user tracking, submit forms without reloading the page, embed multimedia, and even power entire online games. Even deceptively simple-looking pages can often contain multiple pieces of JavaScript. You can find it embedded between `script` tags in the page's source code:

```
<script>
    alert("This creates a pop-up using JavaScript");
</script>
```

A Brief Introduction to JavaScript

Having at least some idea of what is going on in the code you are scraping can be immensely helpful. With that in mind, it's a good idea to familiarize yourself with JavaScript.

JavaScript is a weakly typed language, with a syntax that is often compared to C++ and Java. Although certain elements of the syntax, such as operators, loops, and arrays, might be similar, the weak typing and scriptlike nature of the language can make it a difficult beast to deal with for some programmers.

For example, the following recursively calculates values in the Fibonacci sequence, and prints them to the browser's developer console:

```
<script>
function fibonacci(a, b){
    var nextNum = a + b;
    console.log(nextNum+" is in the Fibonacci sequence");
    if(nextNum < 100){
        fibonacci(b, nextNum);
    }
}
fibonacci(1, 1);
</script>
```

Notice that all variables are identified by preceding them with `var`. This is similar to the `$` sign in PHP, or the type declaration (`int`, `String`, `List`, etc.) in Java or C++. Python is unusual in that it doesn't have this sort of explicit variable declaration.

JavaScript is also extremely good at passing around functions just like variables:

```
<script>
var fibonacci = function() {
    var a = 1;
    var b = 1;
    return function () {
        var temp = b;
        b = a + b;
        a = temp;
        return b;
    }
}
var fibInstance = fibonacci();
console.log(fibInstance()+" is in the Fibonacci sequence");
console.log(fibInstance()+" is in the Fibonacci sequence");
console.log(fibInstance()+" is in the Fibonacci sequence");
</script>
```

This might seem daunting at first, but it becomes simple if you think in terms of lambda expressions (covered in Chapter 2). The variable `fibonacci` is defined as a function. The value of its function returns a function that prints increasingly large

values in the Fibonacci sequence. Each time it is called, it returns the Fibonacci-calculating function, which executes again and increases the values in the function.

Although it might seem convoluted at first glance, some problems, such as calculating Fibonacci values, tend to lend themselves to patterns like this. Passing around functions as variables is also extremely useful when it comes to handling user actions and callbacks, and it is worth getting comfortable with this style of programming when it comes to reading JavaScript.

Common JavaScript Libraries

Although the core JavaScript language is important to know, you can't get far on the modern web without using at least one of the language's many third-party libraries. You might see one or more of these commonly used libraries when looking at page source code.

Executing JavaScript by using Python can be extremely time-consuming and processor intensive, especially if you're doing it on a large scale. Knowing your way around JavaScript and being able to parse it directly (without needing to execute it to acquire the information) can be extremely useful and save you a lot of headaches.

jQuery

jQuery is an extremely common library, used by 70% of the most popular internet sites and about 30% of the rest of the internet.[1] A site using jQuery is readily identifiable because it will contain an import to jQuery somewhere in its code:

```
<script src="http://ajax.googleapis.com/ajax/libs/jquery/1.9.1/jquery.min.js"></
 script>
```

If jQuery is found on a site, you must be careful when scraping it. jQuery is adept at dynamically creating HTML content that appears only after the JavaScript is executed. If you scrape the page's content by using traditional methods, you will retrieve only the preloaded page that appears before the JavaScript has created the content (this scraping problem is covered in more detail in "Ajax and Dynamic HTML" on page 165).

In addition, these pages are more likely to contain animations, interactive content, and embedded media that might make scraping challenging.

1 Dave Methvin's blog post, "The State of jQuery 2014," January 13, 2014, contains a more detailed breakdown of the statistics.

Google Analytics

Google Analytics is used by about 50% of all websites,[2] making it perhaps the most common JavaScript library and the most popular user tracking tool on the internet. Both *http://pythonscraping.com* and *http://www.oreilly.com/* use Google Analytics.

Determining whether a page is using Google Analytics is easy. It will have JavaScript at the bottom, similar to the following (taken from the O'Reilly Media site):

```
<!-- Google Analytics -->
<script type="text/javascript">

var _gaq = _gaq || [];
_gaq.push(['_setAccount', 'UA-4591498-1']);
_gaq.push(['_setDomainName', 'oreilly.com']);
_gaq.push(['_addIgnoredRef', 'oreilly.com']);
_gaq.push(['_setSiteSpeedSampleRate', 50]);
_gaq.push(['_trackPageview']);

(function() { var ga = document.createElement('script'); ga.type =
'text/javascript'; ga.async = true; ga.src = ('https:' ==
document.location.protocol ? 'https://ssl' : 'http://www') +
'.google-analytics.com/ga.js'; var s =
document.getElementsByTagName('script')[0];
s.parentNode.insertBefore(ga, s); })();

</script>
```

This script handles Google Analytics–specific cookies used to track your visit from page to page. This can sometimes be a problem for web scrapers that are designed to execute JavaScript and handle cookies (such as those that use Selenium, discussed later in this chapter).

If a site uses Google Analytics or a similar web analytics system, and you do not want the site to know that it's being crawled or scraped, make sure to discard any cookies used for analytics or discard cookies altogether.

Google Maps

If you've spent any time on the internet, you've almost certainly seen *Google Maps* embedded in a website. Its API makes it extremely easy to embed maps with custom information on any site.

If you're scraping any sort of location data, understanding how Google Maps works makes it easy to obtain well-formatted latitude/longitude coordinates and even addresses. One of the most common ways to denote a location in Google Maps is through a *marker* (also known as a *pin*).

2 W3Techs, "Usage Statistics and Market Share of Google Analytics for Websites".

Markers can be inserted into any Google Map by using code such as the following:

```
var marker = new google.maps.Marker({
      position: new google.maps.LatLng(-25.363882,131.044922),
      map: map,
      title: 'Some marker text'
  });
```

Python makes it easy to extract all instances of coordinates that occur between `google.maps.LatLng(` and `)` to obtain a list of latitude/longitude coordinates.

Using Google's Reverse Geocoding API, you can resolve these coordinate pairs to addresses that are well formatted for storage and analysis.

Ajax and Dynamic HTML

Until now, the only way we've had of communicating with a web server is to send it some sort of HTTP request via the retrieval of a new page. If you've ever submitted a form or retrieved information from a server without reloading the page, you've likely used a website that uses Ajax.

Contrary to what some believe, Ajax is not a language but a group of technologies used to accomplish a certain task (much like web scraping, come to think of it). *Ajax* stands for *Asynchronous JavaScript and XML*, and is used to send information to and receive it from a web server without making a separate page request.

> You should never say, "This website will be written in Ajax." It would be correct to say, "This form will use Ajax to communicate with the web server."

Like Ajax, *dynamic HTML* (DHTML) is a collection of technologies used for a common purpose. DHTML is HTML code, CSS language, or both that changes as client-side scripts change HTML elements on the page. A button might appear only after the user moves the cursor, a background color might change on a click, or an Ajax request might trigger a new block of content to load.

Note that although the word "dynamic" is generally associated with words like "moving," or "changing," the presence of interactive HTML components, moving images, or embedded media does not necessarily make a page DHTML, even though it might look dynamic. In addition, some of the most boring, static-looking pages on the internet can have DHTML processes running behind the scenes that depend on the use of JavaScript to manipulate the HTML and CSS.

If you scrape many websites, you will soon run into a situation in which the content you are viewing in your browser does not match the content you see in the source

code you're retrieving from the site. You might view the output of your scraper and scratch your head, trying to figure out where everything you're seeing on the exact same page in your browser has disappeared to.

The web page might also have a loading page that appears to redirect you to another page of results, but you'll notice that the page's URL never changes when this redirect happens.

Both of these are caused by a failure of your scraper to execute the JavaScript that is making the magic happen on the page. Without the JavaScript, the HTML just sort of sits there, and the site might look very different from what it looks like in your web browser, which executes the JavaScript without problem.

There are several giveaways that a page might be using Ajax or DHTML to change/load the content, but in situations like this, there are only two solutions: scrape the content directly from the JavaScript; or use Python packages capable of executing the JavaScript itself, and scrape the website as you view it in your browser.

Executing JavaScript in Python with Selenium

Selenium is a powerful web scraping tool developed originally for website testing. These days, it's also used when the accurate portrayal of websites—as they appear in a browser—is required. Selenium works by automating browsers to load the website, retrieve the required data, and even take screenshots or assert that certain actions happen on the website.

Selenium does not contain its own web browser; it requires integration with third-party browsers in order to run. If you were to run Selenium with Firefox, for example, you would see a Firefox instance open up on your screen, navigate to the website, and perform the actions you had specified in the code. Although this might be neat to watch, I prefer my scripts to run quietly in the background, so I use a tool called PhantomJS in lieu of an actual browser.

PhantomJS is what is known as a *headless browser*. It loads websites into memory and executes JavaScript on the page, but does it without any graphic rendering of the website to the user. By combining Selenium with PhantomJS, you can run an extremely powerful web scraper that handles cookies, JavaScript, headers, and everything else you need with ease.

You can download the Selenium library from its website or use a third-party installer such as pip to install it from the command line.

PhantomJS can be downloaded from its website. Because PhantomJS is a full (albeit headless) browser and not a Python library, it does require a download and installation to use and cannot be installed with pip.

Although plenty of pages use Ajax to load data (notably Google), I've created a sample page at *http://pythonscraping.com/pages/javascript/ajaxDemo.html* to run your scrapers against. This page contains some sample text, hardcoded into the page's HTML, that is replaced by Ajax-generated content after a two-second delay. If you were to scrape this page's data by using traditional methods, you'd get only the loading page, without getting the data that you want.

The Selenium library is an API called on the object WebDriver. The WebDriver is a bit like a browser in that it can load websites, but it can also be used like a `BeautifulSoup` object to find page elements, interact with elements on the page (send text, click, etc.), and do other actions to drive the web scrapers.

The following code retrieves text behind an Ajax "wall" on the test page:

```
from selenium import webdriver
import time

driver = webdriver.PhantomJS(executable_path='<PhantomJS Path Here>')
driver.get('http://pythonscraping.com/pages/javascript/ajaxDemo.html')
time.sleep(3)
print(driver.find_element_by_id('content').text)
driver.close()
```

Selenium Selectors

In previous chapters, you've selected page elements by using `BeautifulSoup` selectors, such as `find` and `find_all`. Selenium uses an entirely new set of selectors to find an element in a WebDriver's DOM, although they have fairly straightforward names.

In the example, you used the selector `find_element_by_id`, although the following other selectors would have worked as well:

```
driver.find_element_by_css_selector('#content')
driver.find_element_by_tag_name('div')
```

Of course, if you want to select multiple elements on the page, most of these element selectors can return a Python list of elements by using `elements` (i.e., make it plural):

```
driver.find_elements_by_css_selector('#content')
driver.find_elements_by_css_selector('div')
```

If you still want to use BeautifulSoup to parse this content, you can, by using WebDriver's `page_source` function, which returns the page's source, as viewed by the DOM at that current time, as a string:

```
pageSource = driver.page_source
bs = BeautifulSoup(pageSource, 'html.parser')
print(bs.find(id='content').get_text())
```

This creates a new Selenium WebDriver, using the *PhantomJS* library, which tells the WebDriver to load a page and then pauses execution for three seconds before looking at the page to retrieve the (hopefully loaded) content.

Depending on the location of your PhantomJS installation, you might also need to explicitly point Selenium in the right direction when creating a new PhantomJS WebDriver:

```
driver = webdriver.PhantomJS(executable_path='path/to/driver/'\
                             'phantomjs-1.9.8-macosx/bin/phantomjs')
```

If everything is configured correctly, the script should take a few seconds to run and then result in the following text:

```
Here is some important text you want to retrieve!
A button to click!
```

Note that although the page itself contains an HTML button, Selenium's `.text` function retrieves the text value of the button in the same way that it retrieves all other content on the page.

If the `time.sleep` pause is changed to one second instead of three, the text returned changes to the original:

```
This is some content that will appear on the page while it's loading.
 You don't care about scraping this.
```

Although this solution works, it is somewhat inefficient, and implementing it could cause problems on a large scale. Page-load times are inconsistent, depending on the server load at any particular millisecond, and natural variations occur in connection speed. Although this page load should take just over two seconds, you're giving it an entire three seconds to make sure that it loads completely. A more efficient solution would repeatedly check for the existence of a particular element on a fully loaded page and return only when that element exists.

This code uses the presence of the button with the ID `loadedButton` to declare that the page has been fully loaded:

```
from selenium import webdriver
from selenium.webdriver.common.by import By
from selenium.webdriver.support.ui import WebDriverWait
from selenium.webdriver.support import expected_conditions as EC

driver = webdriver.PhantomJS(executable_path='')
driver.get('http://pythonscraping.com/pages/javascript/ajaxDemo.html')
try:
    element = WebDriverWait(driver, 10).until(
                        EC.presence_of_element_located((By.ID, 'loadedButton')))
finally:
    print(driver.find_element_by_id('content').text)
    driver.close()
```

This script has several new imports, most notably `WebDriverWait` and `expected_conditions`, both of which are combined here to form what Selenium calls an *implicit wait*.

An implicit wait differs from an explicit wait in that it waits for a certain state in the DOM to occur before continuing, while an explicit wait defines a hardcoded time as in the previous example, which has a wait of three seconds. In an implicit wait, the triggering DOM state is defined by `expected_condition` (note that the import is cast to `EC` here, a common convention used for brevity). Expected conditions can be many things in the Selenium library, including the following:

- An alert box pops up.
- An element (such as a text box) is put into a *selected* state.
- The page's title changes, or text is now displayed on the page or in a specific element.
- An element is now visible to the DOM, or an element disappears from the DOM.

Most of these expected conditions require that you specify an element to watch for in the first place. Elements are specified using locators. Note that locators are not the same as selectors (see "Selenium Selectors" on page 167 for more on selectors). A *locator* is an abstract query language, using the `By` object, which can be used in a variety of ways, including to make selectors.

In the following code, a locator is used to find elements with the ID `loadedButton`:

```
EC.presence_of_element_located((By.ID, 'loadedButton'))
```

Locators can also be used to create selectors, using the `find_element` WebDriver function:

```
print(driver.find_element(By.ID, 'content').text)
```

That is, of course, functionally equivalent to the line in the example code:

```
print(driver.find_element_by_id('content').text)
```

If you do not need to use a locator, don't; it will save you an import. However, this handy tool is used for a variety of applications and has a great degree of flexibility.

The following locator selection strategies can used with the `By` object:

`ID`
: Used in the example; finds elements by their HTML `id` attribute.

`CLASS_NAME`
: Used to find elements by their HTML `class` attribute. Why is this function `CLASS_NAME` and not simply `CLASS`? Using the form `object.CLASS` would create

problems for Selenium's Java library, where `.class` is a reserved method. To keep the Selenium syntax consistent between languages, `CLASS_NAME` was used instead.

`CSS_SELECTOR`
: Finds elements by their `class`, `id`, or `tag` name, using the `#idName`, `.className`, `tagName` convention.

`LINK_TEXT`
: Finds HTML `<a>` tags by the text they contain. For example, a link labeled "Next" can be selected using `(By.LINK_TEXT, "Next")`.

`PARTIAL_LINK_TEXT`
: Similar to `LINK_TEXT`, but matches on a partial string.

`NAME`
: Finds HTML tags by their `name` attribute. This is handy for HTML forms.

`TAG_NAME`
: Finds HTML tags by their tag name.

`XPATH`
: Uses an `XPath` expression (the syntax of which is described in the following sidebar) to select matching elements.

XPath Syntax

XPath (short for *XML Path*) is a query language used for navigating and selecting portions of an XML document. Founded by the W3C in 1999, it is occasionally used in languages such as Python, Java, and C# when dealing with XML documents.

Although BeautifulSoup does not support XPath, many of the other libraries in this book, such as Scrapy and Selenium, do. It can often be used in the same way as CSS selectors (such as `mytag#idname`), although it is designed to work with more generalized XML documents rather than HTML documents in particular.

The XPath syntax has four major concepts:

- *Root nodes versus nonroot nodes*
  - `/div` will select the div node only if it is at the root of the document.
  - `//div` selects all divs anywhere in the document.
- *Attribute selection*
  - `//@href` selects any nodes with the attribute `href`.
  - `//a[@href='http://google.com']` selects all links in the document that point to Google.
- *Selection of nodes by position*

- `//a[3]` selects the third link in the document.
- `//table[last()]` selects the last table in the document.
- `//a[position() < 3]` selects the first three links in the document.

- *Asterisks (*) match any set of characters or nodes, and can be used in a variety of situations*
  - `//table/tr/*` selects all children of `tr` tags in all tables (this is good for selecting cells using both `th` and `td` tags).
  - `//div[@*]` selects all `div` tags that have any attributes.

XPath syntax also has many advanced features. Over the years, it has developed into a relatively complicated query language, with boolean logic, functions (such as `position()`), and a variety of operators not discussed here.

If you have an HTML or XML selection problem that cannot be addressed by the functions shown here, see Microsoft's XPath Syntax page.

Additional Selenium Webdrivers

In the previous section, the PhantomJS driver was used with Selenium. In most cases, there is little reason to have a browser pop up on the screen and start scraping the web, so headless webdrivers such as PhantomJS can be convenient. However, using a different type of web browser may be useful for running your scrapers for a few reasons:

- Troubleshooting. If your code is running PhantomJS and fails, the failure may be difficult to diagnose without seeing the page in front of you. You can also pause the code execution and interact with the web page as usual at any point.
- Tests may depend on a specific browser in order to run.
- An unusually finicky website or script may behave slightly differently on different browsers. Your code simply may not work in PhantomJS.

Many groups, both official and unofficial, are involved in the creation and maintenance of Selenium webdrivers for every major browser today. The Selenium group curates a collection of these webdrivers for easy reference.

```
firefox_driver = webdriver.Firefox('<path to Firefox webdriver>')
chrome_driver = webdriver.Chrome('<path to Chrome webdriver>')
safari_driver = webdriver.Safari('<path to Safari webdriver>')
ie_driver = webdriver.Ie('<path to Internet Explorer webdriver>')
```

Handling Redirects

Client-side redirects are page redirects that are executed in your browser by JavaScript, rather than a redirect performed on the server, before the page content is sent.

It can sometimes be tricky to tell the difference when visiting a page in your web browser. The redirect might happen so fast that you don't notice any delay in loading time and assume that a client-side redirect is actually a server-side redirect.

However, when scraping the web, the difference is obvious. A server-side redirect, depending on how it is handled, can be easily traversed by Python's `urllib` library without any help from Selenium (for more information on doing this, see Chapter 3). Client-side redirects won't be handled at all unless something is executing the JavaScript.

Selenium is capable of handling these JavaScript redirects in the same way that it handles other JavaScript execution; however, the primary issue with these redirects is when to stop page execution—that is, how to tell when a page is done redirecting. A demo page at *http://pythonscraping.com/pages/javascript/redirectDemo1.html* gives an example of this type of redirect, with a two-second pause.

You can detect that redirect in a clever way by "watching" an element in the DOM when the page initially loads, and then repeatedly calling that element until Selenium throws a `StaleElementReferenceException`; the element is no longer attached to the page's DOM and the site has redirected:

```
from selenium import webdriver
import time
from selenium.webdriver.remote.webelement import WebElement
from selenium.common.exceptions import StaleElementReferenceException

def waitForLoad(driver):
    elem = driver.find_element_by_tag_name("html")
    count = 0
    while True:
        count += 1
        if count > 20:
            print('Timing out after 10 seconds and returning')
            return
        time.sleep(.5)
        try:
            elem == driver.find_element_by_tag_name('html')
        except StaleElementReferenceException:
            return

driver = webdriver.PhantomJS(executable_path='<Path to Phantom JS>')
driver.get('http://pythonscraping.com/pages/javascript/redirectDemo1.html')
waitForLoad(driver)
print(driver.page_source)
```

This script checks the page every half second, with a time-out of 10 seconds, although the times used for the checking time and time-out can be easily adjusted up or down as needed.

Alternatively, you can write a similar loop checking the current URL of the page until the URL changes, or it matches a specific URL that you're looking for.

Waiting for elements to appear and disappear is a common task in Selenium, and you can also use the same `WebDriverWait` function used in the previous button loading example. Here you're providing it a time-out of 15 seconds and an XPath selector that looks for the page body content to accomplish the same task:

```
from selenium.webdriver.common.by import By
from selenium.webdriver.support.ui import WebDriverWait
from selenium.webdriver.support import expected_conditions as EC
from selenium.common.exceptions import TimeoutException

driver = webdriver.PhantomJS(executable_path=
    'drivers/phantomjs/phantomjs-2.1.1-macosx/bin/phantomjs')
driver.get('http://pythonscraping.com/pages/javascript/redirectDemo1.html')
try:
    bodyElement = WebDriverWait(driver, 15).until(EC.presence_of_element_located(
        (By.XPATH, '//body[contains(text(),
        "This is the page you are looking for!)]")))
    print(bodyElement.text)
except TimeoutException:
    print('Did not find the element')
```

A Final Note on JavaScript

Most sites today on the internet use JavaScript.[3] Fortunately for us, this use of JavaScript will not affect how you scrape the page, in many cases. The JavaScript may be limited to powering their tracking tools, controlling a small section of the site, or manipulating a drop-down menu, for example. In cases where it does impact how you scrape the site, the JavaScript can be easily executed with tools like Selenium, in order to produce the simple HTML page you've been learning to scrape in the first part of this book.

Remember: Just because a site uses JavaScript does not mean that all the traditional web scraping tools go out the window. The purpose of JavaScript is ultimately to produce HTML and CSS code that can be rendered by the browser, or to communicate with the server dynamically, through HTTP requests and responses. Once Selenium is used, the HTML and CSS on the page can be read and parsed as you would with any other website code, and HTTP requests and responses can be sent and handled by your code via the techniques in earlier chapters, even without using Selenium.

In addition, JavaScript can even be a benefit to web scrapers, because its use as a "browser-side content management system" may expose useful APIs to the outside

3 W3Techs, "Usage of JavaScript for Websites".

world, letting you obtain the data more directly. For more information on this, see Chapter 12.

If you are still having difficulty with a particularly hairy JavaScript situation, you can find information on Selenium and interacting directly with dynamic websites, including drag-and-drop interfaces, in Chapter 14.

CHAPTER 12

Crawling Through APIs

JavaScript has traditionally been the bane of web crawlers everywhere. At one point in the ancient history of the internet, you could be guaranteed that the request you made to the web server would fetch the same data that the user saw in their web browser when they made that same request.

As JavaScript and Ajax content generation and loading become more ubiquitous, this situation is becoming less common. In Chapter 11, you looked at one way of solving this: using Selenium to automate a browser and fetch the data. This is an easy thing to do. It works almost all of the time.

The problem is that, when you have a "hammer" as powerful and effective as Selenium, every web scraping problem starts to look a lot like a nail.

In this chapter, you'll look at cutting through the JavaScript entirely (no need to execute it or even load it!) and getting straight to the source of the data: the APIs that generate it.

A Brief Introduction to APIs

Although countless books, talks, and guides have been written about the intricacies of REST, GraphQL, JSON, and XML APIs, at their core they are based on a simple concept. An *API* defines a standardized syntax that allows one piece of software to communicate with another piece of software, even though they might be written in different languages or otherwise structured differently.

This section focuses on web APIs (in particular, APIs that allow a web server to communicate to a browser) and uses the term *API* to refer specifically to that type. But you may want to keep in mind that, in other contexts, *API* is also a generic term that can be used to, say, allow a Java program to communicate with a Python program

running on the same machine. An API does not always have to be "across the internet" and does not necessarily involve any web technologies.

Web APIs are most often used by developers who are using a well-advertised and documented public service. For example, ESPN provides APIs for athlete information, game scores, and more. Google has dozens of APIs in its Developers section for language translations, analytics, and geolocation.

The documentation for these APIs typically describes routes or *endpoints*, as URLs that you can request, with variable parameters, either in the path of the URL or as `GET` parameters.

For example, the following provides `pathparam` as a parameter in the route path:

```
http://example.com/the-api-route/pathparam
```

And this provides `pathparam` as the value for the parameter param1:

```
http://example.com/the-api-route?param1=pathparam
```

Both methods of passing variable data to the API are frequently used, although, like many topics in computer science, philosophic debate has raged on when and where variables should be passed through the path or through the parameters.

The response from the API is usually returned in a JSON or XML format. JSON is far more popular in modern times than XML, but you may still see some XML responses. Many APIs allow you to change the response type, usually with the use of another parameter to define which type of response you would like.

Here's an example of a JSON-formatted API response:

```
{"user":{"id": 123, "name": "Ryan Mitchell", "city": "Boston"}}
```

Here's an example of an XML-formatted API response:

```
<user><id>123</id><name>Ryan Mitchell</name><city>Boston</city></user>
```

FreeGeoIP provides an easy-to-use and simple API that translates IP addresses to actual physical addresses. You can try a simple API request by entering the following in your browser:[1]

```
http://freegeoip.net/json/50.78.253.58
```

This should produce the following response:

```
{"ip":"50.78.253.58","country_code":"US","country_name":"United States",
  "region_code":"MA","region_name":"Massachusetts","city":"Boston",
  "zip_code":"02116","time_zone":"America/New_York","latitude":42.3496,
  "longitude":-71.0746,"metro_code":506}
```

1 This API resolves IP addresses to geographic locations and is one you'll be using later in the chapter as well.

Notice that the request contains the parameter `json` in the path. You can request an XML or CSV response by changing this parameter accordingly:

```
http://freegeoip.net/xml/50.78.253.58
http://freegeoip.net/csv/50.78.253.58
```

HTTP Methods and APIs

In the previous section, you looked at APIs making a `GET` request to the server for information. There are four main ways (or *methods*) to request information from a web server via HTTP:

- `GET`
- `POST`
- `PUT`
- `DELETE`

Technically, more than these four exist (such as `HEAD`, `OPTIONS`, and `CONNECT`), but they are rarely used in APIs, and it is unlikely that you will ever see them. The vast majority of APIs limit themselves to these four methods, or even a subset of these four methods. It is common to see APIs that use only `GET`, or use only `GET` and `POST`.

`GET` is what you use when you visit a website through the address bar in your browser. `GET` is the method you are using when you make a call to *http://freegeoip.net/json/50.78.253.58*. You can think of `GET` as saying, "Hey, web server, please retrieve/get me this information."

A `GET` request, by definition, makes no changes to the information in the server's database. Nothing is stored; nothing is modified. Information is only read.

`POST` is what you use when you fill out a form or submit information, presumably to a backend script on the server. Every time you log into a website, you are making a `POST` request with your username and (hopefully) encrypted password. If you are making a `POST` request with an API, you are saying, "Please store this information in your database."

`PUT` is less commonly used when interacting with websites, but is used from time to time in APIs. A `PUT` request is used to update an object or information. An API might require a `POST` request to create a new user, for example, but it might need a `PUT` request if you want to update that user's email address.[2]

2 In reality, many APIs use `POST` requests in lieu of `PUT` requests when updating information. Whether a new entity is created or an old one is merely updated is often left to how the API request itself is structured. However, it's still good to know the difference, and you will often encounter `PUT` requests in commonly used APIs.

DELETE is used, as you might imagine, to delete an object. For instance, if you send a DELETE request to *http://myapi.com/user/23*, it will delete the user with the ID 23. DELETE methods are not often encountered in public APIs, which are primarily created to disseminate information or allow users to create or post information, rather than allow users to remove that information from their databases.

Unlike GET requests, POST, PUT, and DELETE requests allow you to send information in the body of a request, in addition to the URL or route from which you are requesting data.

Just like the response that you receive from the web server, this data in the body is typically formatted as JSON or, less commonly, as XML, and the format of this data is defined by the syntax of the API. For example, if you are using an API that creates comments on blog posts, you might make a PUT request to

```
http://example.com/comments?post=123
```

with the following request body:

```
{"title": "Great post about APIs!", "body": "Very informative. Really helped me
out with a tricky technical challenge I was facing. Thanks for taking the time
to write such a detailed blog post about PUT requests!", "author": {"name": "Ryan
Mitchell", "website": "http://pythonscraping.com", "company": "O'Reilly Media"}}
```

Note that the ID of the blog post (123) is passed as a parameter in the URL, where the content for the new comment you are making is passed in the body of the request. Parameters and data may be passed in both the parameter and the body. Which parameters are required and where they are passed is determined, again, by the syntax of the API.

More About API Responses

As you saw in the FreeGeoIP example at the beginning of the chapter, an important feature of APIs is that they have well-formatted responses. The most common types of response formatting are *eXtensible Markup Language* (XML) and *JavaScript Object Notation* (JSON).

In recent years, JSON has become vastly more popular than XML for a couple of major reasons. First, JSON files are generally smaller than well-designed XML files. Compare, for example, the following XML data, which clocks in at 98 characters:

```
<user><firstname>Ryan</firstname><lastname>Mitchell</lastname><username>Kludgist
</username></user>
```

And now look at the same data in JSON:

```
{"user":{"firstname":"Ryan","lastname":"Mitchell","username":"Kludgist"}}
```

This is only 73 characters, or a whopping 36% smaller than the equivalent XML.

Of course, one could argue that the XML could be formatted like this:

```
<user firstname="ryan" lastname="mitchell" username="Kludgist"></user>
```

But this is considered bad practice because it doesn't support deep nesting of data. Regardless, it still requires 71 characters, about the same length as the equivalent JSON.

Another reason JSON is quickly becoming more popular than XML is due to a shift in web technologies. In the past, it was more common for a server-side script such as PHP or .NET to be on the receiving end of an API. Nowadays, it is likely that a framework, such as Angular or Backbone, will be sending and receiving API calls. Server-side technologies are somewhat agnostic as to the form in which their data comes. But JavaScript libraries like Backbone find JSON easier to handle.

Although APIs are typically thought of as having either an XML response or a JSON response, anything is possible. The response type of the API is limited only by the imagination of the programmer who created it. CSV is another typical response output (as seen in the FreeGeoIP example). Some APIs may even be designed to generate files. A request may be made to a server to generate an image with some particular text overlaid on it, or request a particular XLSX or PDF file.

Some APIs return no response at all. For example, if you are making a request to a server to create a new blog post comment, it may return only an HTTP response code 200, meaning "I posted the comment; everything is great!" Others may return a minimal response like this:

```
{"success": true}
```

If an error occurs, you may get a response like this:

```
{"error": {"message": "Something super bad happened"}}
```

Or if the API is not particularly well configured, you may get a nonparsable stack trace or some plain English text. When making a request to an API, it's usually wise to first check that the response you get is actually JSON (or XML, or CSV, or whatever format you're expecting back).

Parsing JSON

In this chapter, you've looked at various types of APIs and how they function, and you've looked at sample JSON responses from these APIs. Now let's look at how to parse and use this information.

At the beginning of the chapter you saw the example of the *freegeoip.net* IP, which resolves IP addresses to physical addresses:

```
http://freegeoip.net/json/50.78.253.58
```

You can take the output of this request and use Python's JSON-parsing functions to decode it:

```
import json
from urllib.request import urlopen

def getCountry(ipAddress):
    response = urlopen('http://freegeoip.net/json/'+ipAddress).read()
        .decode('utf-8')
    responseJson = json.loads(response)
    return responseJson.get('country_code')

print(getCountry('50.78.253.58'))
```

This prints the country code for the IP address *50.78.253.58*.

The JSON parsing library used is part of Python's core library. Just type in `import json` at the top, and you're all set! Unlike many languages that might parse JSON into a special JSON object or JSON node, Python uses a more flexible approach and turns JSON objects into dictionaries, JSON arrays into lists, JSON strings into strings, and so forth. In this way, it is extremely easy to access and manipulate values stored in JSON.

The following gives a quick demonstration of how Python's JSON library handles the values that might be encountered in a JSON string:

```
import json

jsonString = '{"arrayOfNums":[{"number":0},{"number":1},{"number":2}],
               "arrayOfFruits":[{"fruit":"apple"},{"fruit":"banana"},
                                {"fruit":"pear"}]}'
jsonObj = json.loads(jsonString)

print(jsonObj.get('arrayOfNums'))
print(jsonObj.get('arrayOfNums')[1])
print(jsonObj.get('arrayOfNums')[1].get('number') +
      jsonObj.get('arrayOfNums')[2].get('number'))
print(jsonObj.get('arrayOfFruits')[2].get('fruit'))
```

Here is the output:

```
[{'number': 0}, {'number': 1}, {'number': 2}]
{'number': 1}
3
pear
```

Line 1 is a list of dictionary objects, line 2 is a dictionary object, line 3 is an integer (the sum of the integers accessed in the dictionaries), and line 4 is a string.

Undocumented APIs

So far in this chapter, we've discussed only APIs that are documented. Their developers intend them to be used by the public, publish information about them, and assume that the APIs will be used by other developers. But the vast majority of APIs don't have any published documentation at all.

But why would you create an API without any public documentation? As mentioned in the beginning of this chapter, it all has to do with JavaScript.

Traditionally, the web servers for dynamic websites had several tasks whenever a user requested a page:

- Handle `GET` requests from users requesting a page of a website
- Retrieve the data from the database that appears on that page
- Format the data into the HTML template for the page
- Send that formatted HTML to the user

As JavaScript frameworks became more ubiquitous, many of the HTML creation tasks handled by the server moved into the browser. The server might send a hardcoded HTML template to the user's browser, but separate Ajax requests would be made to load the content and place it in the correct slots in that HTML template. All this would happen on the browser/client side.

This was initially a problem for web scrapers. They were used to making a request for an HTML page and getting back exactly that—an HTML page with all of the content already in place. Instead, they now got an HTML template without any content.

Selenium was used to solve this problem. Now the programmer's web scraper could become the browser, request the HTML template, execute any JavaScript, allow all the data to load in its place, and only *then* scrape the page for data. Because the HTML was all loaded, it was essentially reduced to a previously solved problem—the problem of parsing and formatting existing HTML.

However, because the entire content management system (that used to reside only in the web server) had essentially moved to the browser client, even the simplest websites could balloon into several megabytes of content and a dozen HTTP requests.

In addition, when Selenium is used, all of the "extras" that the user doesn't necessarily care about are loaded. Calls to tracking programs, loading sidebar ads, calls to tracking programs for the sidebar ads. Images, CSS, third-party font data—all of it needs to be loaded. This may seem great when you're using a browser to browse the web, but if you're writing a web scraper that needs to move fast, collect specific data, and place as little of a load on the web server as possible, you can be loading a hundred times more data than you need.

But there's a silver lining to all of this JavaScript, Ajax, and web modernization: because servers are no longer formatting the data into HTML, they often act as thin wrappers around the database itself. This thin wrapper simply extracts data from the database, and returns it to the page via an API.

Of course, these APIs aren't meant to be used by anyone or anything besides the webpage itself, and so developers leave them undocumented and assume (or hope) that no one will notice them. But they do exist.

The *New York Times* website, for example, loads all of its search results via JSON. If you visit the link

```
https://query.nytimes.com/search/sitesearch/#/python
```

this will reveal recent news articles for the search term "python." If you scrape this page using urllib or the Requests library, you won't find any search results. These are loaded separately via an API call:

```
https://query.nytimes.com/svc/add/v1/sitesearch.json
?q=python&spotlight=true&facet=true
```

If you were to load this page with Selenium, you would be making about 100 requests and transferring 600–700 kB of data with each search. Using the API directly, you make only one request and transfer approximately only the 60 kb of nicely formatted data that you need.

Finding Undocumented APIs

You've used the Chrome inspector in previous chapters to examine the contents of an HTML page, but now you'll use it for a slightly different purpose: to examine the requests and responses of the calls that are used to construct that page.

To do this, open the Chrome inspector window and click the Network tab, shown in Figure 12-1.

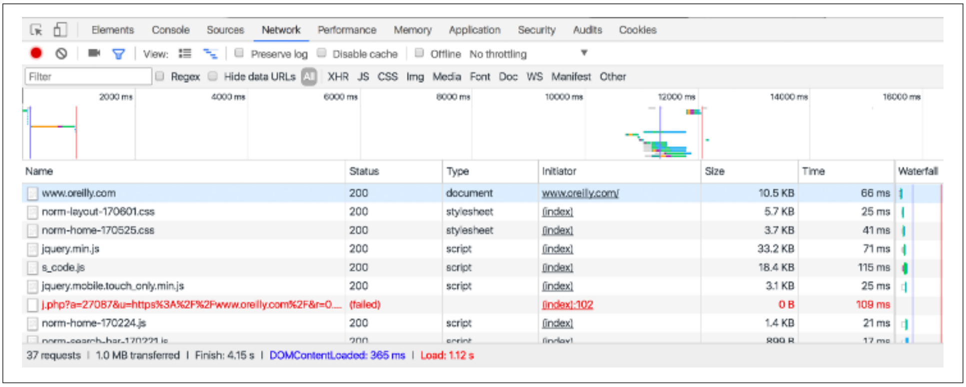


Figure 12-1. The Chrome network inspector tool provides a view into all calls your browser is making and receiving

Note that you need to open this window before the page loads. It does not track network calls while it's closed.

While the page is loading, you'll see a line appear in real time whenever your browser makes a call back to the web server for additional information to render the page. This may include an API call.

Finding undocumented APIs can take a little detective work (to take the detective work out of this, see "Finding and Documenting APIs Automatically" on page 184), especially with larger sites with lots of network calls. Generally, though, you'll know it when you see it.

API calls tend to have several features that are useful for locating them in the list of network calls:

- They often have JSON or XML in them. You can filter the list of requests by using the search/filter field.
- With `GET` requests, the URL will contain the parameter values passed to them. This will be useful if, for example, you're looking for an API call that returns the results of a search or is loading data for a specific page. Simply filter the results with the search term you used, page ID, or other identifying information.
- They will usually be of the type XHR.

APIs may not always be obvious, especially in large sites with lots of features that may make hundreds of calls while loading a single page. However, spotting the metaphorical needle in the haystack becomes much easier with a little practice.

Documenting Undocumented APIs

After you've found an API call being made, it's often useful to document it to some extent, especially if your scrapers will rely heavily on the call. You may want to load several pages on the website, filtering for the target API call in the inspector console network tab. By doing this, you can see how the call changes from page to page, and identify the fields that it accepts and returns.

Every API call can be identified and documented by paying attention to the following fields:

- HTTP method used
- Inputs
  - Path parameters
  - Headers (including cookies)
  - Body content (for `PUT` and `POST` calls)
- Outputs
  - Response headers (including cookies set)
  - Response body type
  - Response body fields

Finding and Documenting APIs Automatically

The work of locating and documenting APIs can seem somewhat tedious and algorithmic. This is mostly because it is. While some websites may attempt to obfuscate how the browser is getting its data, which makes the task a little trickier, finding and documenting APIs is mostly a programmatic task.

I've created a GitHub repository at *https://github.com/REMitchell/apiscraper* that attempts to take some of the grunt work out of this task.

It uses Selenium, ChromeDriver, and a library called BrowserMob Proxy to load pages, crawl pages within a domain, analyze the network traffic that occurs during page load, and organize these requests into readable API calls.

Several moving parts are required to get this project running. The first, is the software itself.

Clone the apiscraper GitHub project. The cloned project should contain the following files:

apicall.py
: Contains attributes that define an API call (path, parameters, etc.) as well as logic to decide whether two API calls are the same.

apiFinder.py
: Main crawling class. Used by *webservice.py* and *consoleservice.py* to kick off the process of finding APIs.

browser.py
: Has only three methods—`initialize`, `get`, and `close`—but encompasses relatively complicated functionality to tie together the BrowserMob Proxy server and Selenium. Scrolls through pages to ensure that the entire page is loaded, saves HTTP Archive (HAR) files to the appropriate location for processing.

consoleservice.py
: Handles commands from the console and kicks off the main `APIFinder` class.

harParser.py
: Parses HAR files and extracts API calls.

html_template.html
: Provides a template to display API calls in the browser.

README.md
: Git readme page.

Download the BrowserMob Proxy binary files from *https://bmp.lightbody.net/* and place the extracted files in the *apiscraper* project directory.

As of this writing, the current version of BrowserMob Proxy is 2.1.4, so this script will assume that the binary files are at *browsermob-proxy-2.1.4/bin/browsermob-proxy* relative to the root project directory. If this is not the case, you can provide a different directory at runtime, or (perhaps easier) modify the code in *apiFinder.py*.

Download *ChromeDriver* and place this in the apiscraper project directory.

You'll need to have the following Python libraries installed:

- `tldextract`
- `selenium`
- `browsermob-proxy`

When this setup is done, you're ready to start collecting API calls. Typing

```
$ python consoleservice.py -h
```

will present you with a list of options to get started:

```
usage: consoleservice.py [-h] [-u [U]] [-d [D]] [-s [S]] [-c [C]] [-i [I]]
                         [--p]

optional arguments:

  -h, --help  show this help message and exit

  -u [U]      Target URL. If not provided, target directory will be scanned
              for har files.

  -d [D]      Target directory (default is "hars"). If URL is provided,
              directory will store har files. If URL is not provided,
              directory will be scanned.

  -s [S]      Search term

  -c [C]      File containing JSON formatted cookies to set in driver (with
              target URL only)

  -i [I]      Count of pages to crawl (with target URL only)

  --p         Flag, remove unnecessary parameters (may dramatically increase
              runtime)
```

You can search for API calls made on a single page for a single search term. For example, you can search a page on *http://target.com* for an API returning product data to populate the product page:

```
$ python consoleservice.py -u https://www.target.com/p/rogue-one-a-star-wars-\
story-blu-ray-dvd-digital-3-disc/-/A-52030319 -s "Rogue One: A Star Wars Story"
```

This returns information, including a URL, for an API that returns product data for that page:

```
URL: https://redsky.target.com/v2/pdp/tcin/52030319
METHOD: GET
AVG RESPONSE SIZE: 34834
SEARCH TERM CONTEXT: c":"786936852318","product_description":{"title":
"Rogue One: A Star Wars Story (Blu-ray + DVD + Digital) 3 Disc",
"long_description":...
```

Using the `-i` flag, multiple pages can be crawled (this defaults to just one page), starting from the provided URL. This can be useful for searching all network traffic for particular keywords, or, by omitting the `-s` search term flag, collecting all API traffic that occurs when loading each page.

All collected data is stored as a HAR file, in the default directory */har* in the project root, although this directory can be changed with the `-d` flag.

If no URL is provided, you can also pass in a directory of precollected HAR files for searching and analysis.

This project provides many other features, including the following:

- Unnecessary parameter removal (removing `GET` or `POST` parameters that do not influence the return value of the API call)
- Multiple API output formats (command line, HTML, JSON)
- Distinguishing between path parameters that indicate a separate API route, and path parameters that act merely as `GET` params for the same API route

Further development is also planned as I, and others, continue to use it for web scraping and API collection.

Combining APIs with Other Data Sources

Although the raison d'être of many modern web applications is to take existing data and format it in a more appealing way, I would argue that this isn't an interesting thing to do in most instances. If you're using an API as your only data source, the best you can do is merely copy someone else's database that already exists, and which is, essentially, already published. What can be far more interesting is to take two or more data sources and combine them in a novel way, or use an API as a tool to look at scraped data from a new perspective.

Let's look at one example of how data from APIs can be used in conjunction with web scraping to see which parts of the world contribute the most to Wikipedia.

If you've spent much time on Wikipedia, you've likely come across an article's revision history page, which displays a list of recent edits. If users are logged into Wikipedia when they make the edit, their username is displayed. If they are not logged in, their IP address is recorded, as shown in Figure 12-2.

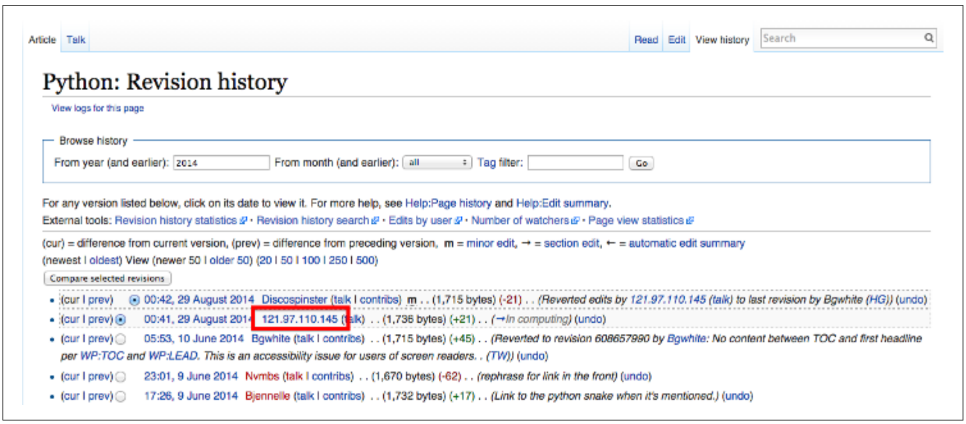


Figure 12-2. The IP address of an anonymous editor on the revision history page for Wikipedia's Python entry

The IP address provided on the history page is *121.97.110.145*. By using the *freegeoip.net* API, that IP address is from Quezon, Philippines as of this writing (IP addresses can occasionally shift geographically).

This information isn't all that interesting on its own, but what if you could gather many points of geographic data about Wikipedia edits and where they occur? A few years ago, I did just that and used Google's GeoChart library to create an interesting chart that shows where edits on the English-language Wikipedia, along with the Wikipedias written in other languages, originate from (Figure 12-3).

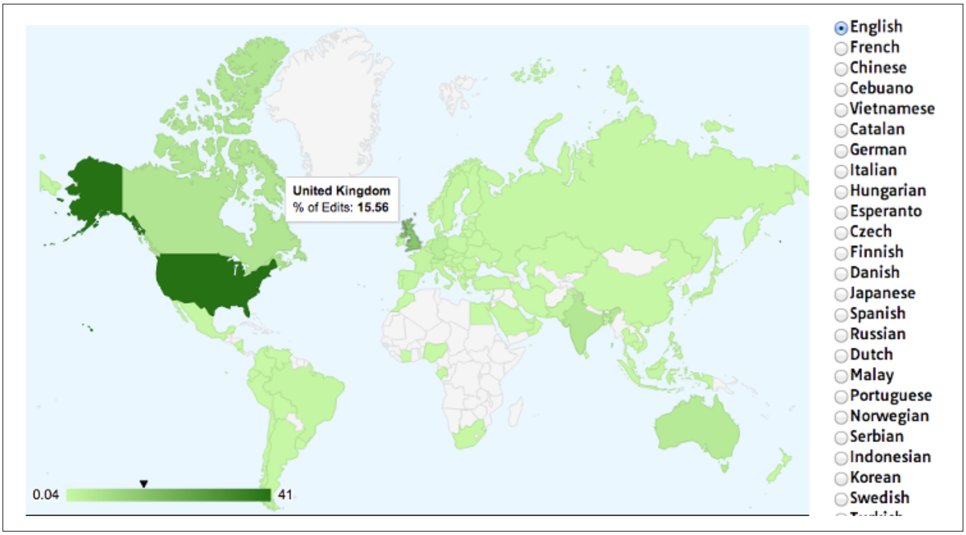


Figure 12-3. Visualization of Wikipedia edits created using Google's GeoChart library

Creating a basic script that crawls Wikipedia, looks for revision history pages, and then looks for IP addresses on those revision history pages isn't difficult. Using modified code from Chapter 3, the following script does just that:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import json
import datetime
import random
import re

random.seed(datetime.datetime.now())
def getLinks(articleUrl):
    html = urlopen('http://en.wikipedia.org{}'.format(articleUrl))
    bs = BeautifulSoup(html, 'html.parser')
    return bs.find('div', {'id':'bodyContent'}).findAll('a',
        href=re.compile('^(/wiki/)((?!:).)*$'))

def getHistoryIPs(pageUrl):
```

```
    #Format of revision history pages is:
    #http://en.wikipedia.org/w/index.php?title=Title_in_URL&action=history
    pageUrl = pageUrl.replace('/wiki/', '')
    historyUrl = 'http://en.wikipedia.org/w/index.php?title={}&action=history'
        .format(pageUrl)
    print('history url is: {}'.format(historyUrl))
    html = urlopen(historyUrl)
    bs = BeautifulSoup(html, 'html.parser')
    #finds only the links with class "mw-anonuserlink" which has IP addresses
    #instead of usernames
    ipAddresses = bs.findAll('a', {'class':'mw-anonuserlink'})
    addressList = set()
    for ipAddress in ipAddresses:
        addressList.add(ipAddress.get_text())
    return addressList

links = getLinks('/wiki/Python_(programming_language)')

while(len(links) > 0):
    for link in links:
        print('-'*20)
        historyIPs = getHistoryIPs(link.attrs['href'])
        for historyIP in historyIPs:
            print(historyIP)

    newLink = links[random.randint(0, len(links)-1)].attrs['href']
    links = getLinks(newLink)
```

This program uses two main functions: `getLinks` (which was also used in Chapter 3), and the new `getHistoryIPs`, which searches for the contents of all links with the class `mw-anonuserlink` (indicating an anonymous user with an IP address, rather than a username) and returns it as a set.

This code also uses a somewhat arbitrary (yet effective for the purposes of this example) search pattern to look for articles from which to retrieve revision histories. It starts by retrieving the histories of all Wikipedia articles linked to by the starting page (in this case, the article on the Python programming language). Afterward, it randomly selects a new starting page, and retrieves all revision history pages of articles linked to by that page. It will continue until it hits a page with no links.

Now that you have code that retrieves IP addresses as a string, you can combine this with the `getCountry` function from the previous section in order to resolve these IP addresses to countries. You'll modify `getCountry` slightly, in order to account for invalid or malformed IP addresses that will result in a 404 Not Found error (as of this writing, FreeGeoIP does not resolve IPv6, for instance, which might trigger such an error):

```
def getCountry(ipAddress):
    try:
```

```
        response = urlopen(
            'http://freegeoip.net/json/{}'.format(ipAddress)).read().decode('utf-8')
    except HTTPError:
        return None
    responseJson = json.loads(response)
    return responseJson.get('country_code')

links = getLinks('/wiki/Python_(programming_language)')

while(len(links) > 0):
    for link in links:
        print('-'*20)
        historyIPs = getHistoryIPs(link.attrs["href"])
        for historyIP in historyIPs:
            country = getCountry(historyIP)
            if country is not None:
                print('{} is from {}'.format(historyIP, country))

    newLink = links[random.randint(0, len(links)-1)].attrs['href']
    links = getLinks(newLink)
```

Here's the sample output:

```
-------------------
history url is: http://en.wikipedia.org/w/index.php?title=Programming_
paradigm&action=history
68.183.108.13 is from US
86.155.0.186 is from GB
188.55.200.254 is from SA
108.221.18.208 is from US
141.117.232.168 is from CA
76.105.209.39 is from US
182.184.123.106 is from PK
212.219.47.52 is from GB
72.27.184.57 is from JM
49.147.183.43 is from PH
209.197.41.132 is from US
174.66.150.151 is from US
```

More About APIs

This chapter has shown a few ways that modern APIs are commonly used to access data on the web, and how those APIs can be used to build faster and more powerful web scrapers. If you're looking to build APIs instead of just using them, or if you want to learn more about the theory of their construction and syntax, I recommend *RESTful Web APIs* by Leonard Richardson, Mike Amundsen, and Sam Ruby (O'Reilly). This book provides a strong overview of the theory and practice of using APIs on the web. In addition, Mike Amundsen has a fascinating video series, *Designing APIs for the Web* (O'Reilly), that teaches you how to create your own APIs—a useful thing to

know if you decide to make your scraped data available to the public in a convenient format.

While some might bemoan the ubiquity of JavaScript and dynamic websites, making traditional "grab and parse the HTML page" practices outdated, I, for one, welcome our new robot overlords. As dynamic websites rely less on HTML pages for human consumption and more on strictly formatted JSON files for HTML consumption, this provides a boon for everyone trying to get clean, well-formatted data.

The web is no longer a collection of HTML pages with occasional multimedia and CSS adornments. It's a collection of hundreds of file types and data formats, whizzing hundreds at a time to form the pages that you consume through your browser. The real trick is often to look beyond the page in front of you and grab the data at its source.

CHAPTER 13

Image Processing and Text Recognition

From Google's self-driving cars to vending machines that recognize counterfeit currency, machine vision is a huge field with far-reaching goals and implications. This chapter focuses on one small aspect of the field: text recognition—specifically, how to recognize and use text-based images found online by using a variety of Python libraries.

Using an image in lieu of text is a common technique when you don't want text to be found and read by bots. This is often seen on contact forms when an email address is partially or completely rendered as an image. Depending on how skillfully it is done, it might not even be noticeable to human viewers, but bots have a difficult time reading these images, and the technique is enough to stop most spammers from acquiring your email address.

CAPTCHAs, of course, take advantage of the fact that users can read security images but most bots can't. Some CAPTCHAs are more difficult than others, an issue we'll tackle later in this book.

But CAPTCHAs aren't the only place on the web where scrapers need image-to-text translation assistance. Even in this day and age, many documents are scanned from hard copies and put on the web, making these documents inaccessible as far as much of the internet is concerned, although they are "hiding in plain sight." Without image-to-text capabilities, the only way to make these documents accessible is for a human to type them up by hand—and nobody has time for that.

Translating images into text is called *optical character recognition*, or *OCR*. A few major libraries can perform OCR, and many other libraries support them or are built on top of them. This system of libraries can get fairly complicated at times, so I recommend you read the next section before attempting any of the exercises in this chapter.

Overview of Libraries

Python is a fantastic language for image processing and reading, image-based machine-learning, and even image creation. Although many libraries can be used for image processing, we will focus on two: Pillow and Tesseract.

These two libraries make for a powerful complementary duo when it comes to processing and doing OCR on images from around the web. *Pillow* performs the first pass, cleaning and filtering images, and *Tesseract* attempts to match the shapes found in those images to its library of known text.

This chapter covers their installation and basic usage, along with several examples of this library duo working together. We'll also cover some advanced Tesseract training, so that you can train Tesseract to OCR additional fonts and languages (or even CAPTCHAs) that you might encounter on the web.

Pillow

Although Pillow might not be the most fully featured image-processing library, it has all the features you are likely to need and then some—unless you plan to rewrite Photoshop in Python, in which case you're reading the wrong book! Pillow also has the advantage of being one of the better-documented third-party libraries and is extremely easy to use out of the box.

Forked off the Python Imaging Library (PIL) for Python 2.x, Pillow adds support for Python 3.x. Like its predecessor, Pillow allows you to easily import and manipulate images with a variety of filters, masks, and even pixel-specific transformations:

```
from PIL import Image, ImageFilter

kitten = Image.open('kitten.jpg')
blurryKitten = kitten.filter(ImageFilter.GaussianBlur)
blurryKitten.save('kitten_blurred.jpg')
blurryKitten.show()
```

In the preceding example, the image *kitten.jpg* will open in your default image viewer with a blur added to it and will also be saved in its blurrier state as *kitten_blurred.jpg* in the same directory.

You will use Pillow to perform preprocessing on images to make them more machine readable, but as mentioned before, you can do many other things with the library aside from these simple filter applications. For more information, check out the Pillow documentation.

Tesseract

Tesseract is an OCR library. Sponsored by Google (a company obviously well-known for its OCR and machine-learning technologies), Tesseract is widely regarded to be the best, most accurate, open source OCR system available.

In addition to being accurate, it is also extremely flexible. It can be trained to recognize any number of fonts (as long as those fonts are relatively consistent within themselves, as you will see soon). It also can be expanded to recognize any Unicode character.

This chapter uses both the command-line program *Tesseract* along with its third-party Python wrapper *pytesseract*. Both will be explicitly named as one of these two, so know that when you see "Tesseract," I'm referring to the command-line software, and when you see "pytesseract," I'm specifically referring to its third-party Python wrapper.

Installing Tesseract

For Windows users, there is a convenient executable installer. As of this writing, the current version is 3.02, although newer versions should be fine as well.

Linux users can install Tesseract with `apt-get`:

```
$ sudo apt-get tesseract-ocr
```

Installing Tesseract on a Mac is slightly more complicated, although it can be done easily with many third-party installers such as Homebrew, which was used in Chapter 6 to install MySQL. For example, you can install Homebrew and use it to install Tesseract in two lines:

```
$ ruby -e "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/ \
           install/master/install)"
$ brew install tesseract
```

Tesseract also can be installed from the source, on the project's download page.

To use some features of Tesseract, such as training the software to recognize new characters later in this section, you also need to set a new environment variable, `$TESSDATA_PREFIX`, to let it know where data files are stored.

You can do this in most Linux systems and on macOS as follows:

```
$ export TESSDATA_PREFIX=/usr/local/share/
```

Note that */usr/local/share/* is the default data location for Tesseract, although you should check to make sure that this is the case for your own installation.

Similarly, on Windows, you can use the following to use the environment variable:

```
# setx TESSDATA_PREFIX C:\Program Files\Tesseract OCR\
```

pytesseract

After Tesseract is installed, you're ready to install the Python wrapper library, *pytesseract*, which uses your existing Tesseract installation to read image files and output strings and objects that can be used in Python scripts.

> **Code Samples Require pytesseract 0.1.9**
>
> Be aware that some significant changes occurred (with contributions from the author) between versions 0.1.8 and 0.1.9 of *pytesseract*. This section covers features found only in version 0.1.9 of the library. Please be sure you are installing the correct version when running code samples in this chapter.

As usual, you can install pytesseract via pip, or by downloading from the pytesseract project page and running:

```
$ python setup.py install
```

Pytesseract can be used in conjunction with PIL to read text from images:

```
from PIL import Image
import pytesseract

print(pytesseract.image_to_string(Image.open('files/test.png')))
```

If your *Tesseract* library is installed in your Python path, you can point pytesseract to the location by including this line:

```
pytesseract.pytesseract.tesseract_cmd = '/path/to/tesseract'
```

Pytesseract has several useful features in addition to returning the OCR results of an image as in the code sample above. It can estimate box files (pixel locations for the boundaries of each character):

```
print(pytesseract.image_to_boxes(Image.open('files/test.png')))
```

It can also return a complete output of all data, such as confidence scores, page and line numbers, box data, as well as other information:

```
print(pytesseract.image_to_data(Image.open('files/test.png')))
```

The default output for these last two files is as space- or tab-delimited string files, but you can also get output as dictionaries or (if decoding in UTF-8 isn't sufficient) byte strings:

```
from PIL import Image
import pytesseract
from pytesseract import Output

print(pytesseract.image_to_data(Image.open('files/test.png'),
    output_type=Output.DICT))
```

```
print(pytesseract.image_to_string(Image.open('files/test.png'),
    output_type=Output.BYTES))
```

This chapter uses a combination of the *pytesseract* library, as well as command-line Tesseract, and triggering Tesseract from Python via the `subprocess` library. Although the pytesseract library is useful and convenient, there are some Tesseract functions it cannot do, so it's good to be familiar with all methods.

NumPy

Although NumPy is not required for straightforward OCR, you will need it if you want to train Tesseract to recognize additional character sets or fonts introduced later in this chapter. You will also be using it for simple math tasks (such as weighted averages) in some of the code samples later.

NumPy is a powerful library used for linear algebra and other large-scale math applications. NumPy works well with Tesseract because of its ability to mathematically represent and manipulate images as large arrays of pixels.

NumPy can be installed using any third-party Python installer such as pip, or by downloading the package and installing with `$ python setup.py install`.

Even if you don't plan on running any of the code samples that use it, I highly recommend installing it or adding it to your Python arsenal. It serves to round out Python's built-in math library and has many useful features, particularly for operations with lists of numbers.

By convention, NumPy is imported as `np` and can be used as follows:

```
import numpy as np

numbers = [100, 102, 98, 97, 103]
print(np.std(numbers))
print(np.mean(numbers))
```

This example prints the standard deviation and mean of the set of numbers provided to it.

Processing Well-Formatted Text

With any luck, most of the text that you'll need to process will be relatively clean and well formatted. Well-formatted text generally meets several requirements, although the line between what is "messy" and what is "well formatted" can be subjective.

In general, well-formatted text:

- is written in one standard font (excluding handwriting fonts, cursive fonts, or excessively decorative fonts);

- if copied or photographed, has extremely crisp lines, with no copying artifacts or dark spots;
- is well aligned, without slanted letters; and
- does not run off the image, nor is there cut-off text or margins on the edges of the image

Some of these things can be fixed in preprocessing. For instance, images can be converted to grayscale, brightness and contrast can be adjusted, and the image can be cropped and rotated as needed. However, some fundamental limitations might require more-extensive training. See "Reading CAPTCHAs and Training Tesseract" on page 206.

Figure 13-1 is an ideal example of well-formatted text.

Figure 13-1. Sample text saved as a .tiff file, to be read by Tesseract

You can run Tesseract from the command line to read this file and write the results to a text file:

```
$ tesseract text.tif textoutput | cat textoutput.txt
```

The output is a line of information about the *Tesseract* library to indicate that it is running, followed by the contents of the newly created *textoutput.txt*:

```
Tesseract Open Source OCR Engine v3.02.02 with Leptonica
This is some text, written in Arial, that will be read by
Tesseract. Here are some symbols: !@#$%"&'()
```

You can see that the results are mostly accurate, although the symbols ^ and * were interpreted as a double quote and single quote, respectively. On the whole, though, this lets you read the text fairly comfortably.

After blurring the image text, creating some JPG compression artifacts, and adding a slight background gradient, the results get much worse (see Figure 13-2).

Figure 13-2. Unfortunately, many of the documents you will encounter on the internet will look more like this than the previous example

Tesseract is not able to deal with this image nearly as well mainly because of the background gradient and produces the following output:

```
This is some text, written In Arlal, that"
Tesseract. Here are some symbols: _
```

Notice that the text is cut off as soon as the background gradient makes the text more difficult to distinguish, and that the last character from each line is wrong, as Tesseract tries futilely to make sense of it. In addition, the JPG artifacts and blurring make it difficult for Tesseract to distinguish between a lowercase *i* and an uppercase *I* and the number *1*.

This is where using a Python script to clean your images first comes in handy. Using the Pillow library, you can create a threshold filter to get rid of the gray in the background, bring out the text, and make the image clearer for Tesseract to read.

In addition, instead of using Tesseract from the command line, you can use the pytesseract library to run the Tesseract commands and read the resulting file for:

```
from PIL import Image
import pytesseract

def cleanFile(filePath, newFilePath):
    image = Image.open(filePath)

    #Set a threshold value for the image, and save
    image = image.point(lambda x: 0 if x < 143 else 255)
    image.save(newFilePath)
    return image

image = cleanFile('files/textBad.png', 'files/textCleaned.png')

#call tesseract to do OCR on the newly created image
print(pytesseract.image_to_string(image))
```

The resulting image, automatically created as *textCleaned.png*, is shown in Figure 13-3.

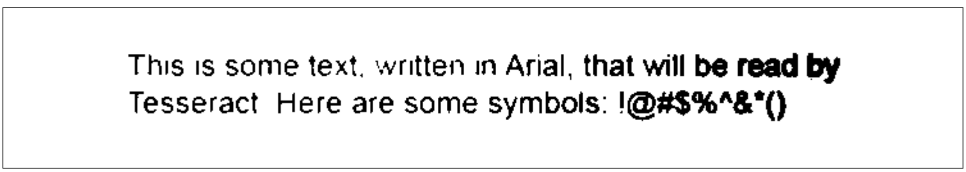


Figure 13-3. This image was created by passing the previous "messy" version of the image through a threshold filter

Apart from some barely legible or missing punctuation, the text is readable, at least to us. Tesseract gives it its best shot:

```
This us some text‘ written In Anal, that will be read by
Tesseract Here are some symbols: !@#$%"&'()
```

The periods and commas, being extremely small, are the first victims of this image wrangling and nearly disappear, both from our view and Tesseract's. There's also the unfortunate misinterpretation of "Arial" as "Anal," the result of Tesseract interpreting the *r* and the *i* as the single character *n*.

Still, it's an improvement over the previous version, in which nearly half of the text was cut off.

Tesseract's greatest weakness seems to be backgrounds with varying brightness. Tesseract's algorithms attempt to adjust the contrast of the image automatically before reading the text, but you can probably get better results doing this yourself with a tool like the Pillow library.

Images you should definitely fix before submitting to Tesseract are those that are tilted, have large areas of nontext, or have other problems.

Adjusting Images Automatically

In the previous example, the value 143 was chosen experimentally as the "ideal" threshold to adjust all image pixels to black or white, in order for Tesseract to read the image. But what if you have many images, all with slightly different grayscale problems and aren't reasonably able to go and adjust all of them by hand?

One way to find the best solution (or at least, a pretty good one) is to run Tesseract against a range of images adjusted to different values and algorithmically choose the one with the best result, as measured by some combination of the number of characters and/or strings Tesseract is able to read, and the "confidence" that it reads those characters with.

Which algorithm you use, exactly, may vary slightly from application to application, but this is one example of iterating through image-processing thresholds in order to find the "best" setting:

```python
import pytesseract
from pytesseract import Output
from PIL import Image
import numpy as np

def cleanFile(filePath, threshold):
    image = Image.open(filePath)
    #Set a threshold value for the image, and save
    image = image.point(lambda x: 0 if x < threshold else 255)
    return image

def getConfidence(image):
    data = pytesseract.image_to_data(image, output_type=Output.DICT)
```

```
    text = data['text']
    confidences = []
    numChars = []

    for i in range(len(text)):
        if data['conf'][i] > -1:
            confidences.append(data['conf'][i])
            numChars.append(len(text[i]))

    return np.average(confidences, weights=numChars), sum(numChars)

filePath = 'files/textBad.png'

start = 80
step = 5
end = 200

for threshold in range(start, end, step):
    image = cleanFile(filePath, threshold)
    scores = getConfidence(image)
    print("threshold: " + str(threshold) + ", confidence: "
        + str(scores[0]) + " numChars " + str(scores[1]))
```

This script has two functions:

`cleanFile`
: Takes in an original "bad" file and a threshold variable to run the PIL threshold tool with. It processes the file and returns the PIL image object.

`getConfidence`
: Takes in the cleaned PIL image object and runs it through Tesseract. It calculates the average confidence of each recognized string (weighted by the number of characters in that string), as well as the number of recognized characters.

By varying the threshold value and getting the confidence and number of recognized characters at each value, you get the output:

```
threshold: 80, confidence: 61.8333333333 numChars 18
threshold: 85, confidence: 64.9130434783 numChars 23
threshold: 90, confidence: 62.2564102564 numChars 39
threshold: 95, confidence: 64.5135135135 numChars 37
threshold: 100, confidence: 60.7878787879 numChars 66
threshold: 105, confidence: 61.9078947368 numChars 76
threshold: 110, confidence: 64.6329113924 numChars 79
threshold: 115, confidence: 69.7397260274 numChars 73
threshold: 120, confidence: 72.9078947368 numChars 76
threshold: 125, confidence: 73.582278481 numChars 79
threshold: 130, confidence: 75.6708860759 numChars 79
threshold: 135, confidence: 76.8292682927 numChars 82
threshold: 140, confidence: 72.1686746988 numChars 83
threshold: 145, confidence: 75.5662650602 numChars 83
threshold: 150, confidence: 77.5443037975 numChars 79
```

```
threshold: 155, confidence: 79.1066666667 numChars 75
threshold: 160, confidence: 78.4666666667 numChars 75
threshold: 165, confidence: 80.1428571429 numChars 70
threshold: 170, confidence: 78.4285714286 numChars 70
threshold: 175, confidence: 76.3731343284 numChars 67
threshold: 180, confidence: 76.7575757576 numChars 66
threshold: 185, confidence: 79.4920634921 numChars 63
threshold: 190, confidence: 76.0793650794 numChars 63
threshold: 195, confidence: 70.6153846154 numChars 65
```

There is a clear trend among both the average confidence in the result, as well as the number of characters recognized. Both tend to peak around a threshold of 145, which is close to the manually found "ideal" result of 143.

Thresholds of both 140 and 145 give the maximum number of recognized characters (83), but a threshold of 145 gives the highest confidence for those found characters, so you may want to go with that result and return the text that was recognized at that threshold as the "best guess" for what text the image contains.

Of course, simply finding the "most" characters does not necessarily mean that all of those characters are real. At some thresholds, Tesseract could split single characters into multiple ones, or interpret random noise in the image as a text character that doesn't actually exist. In this case, you may want to rely more heavily on the average confidence of each score.

For example, if you find results that read (in part) as follows:

```
threshold: 145, confidence: 75.5662650602 numChars 83
threshold: 150, confidence: 97.1234567890 numChars 82
```

it would probably be a no-brainer to go with the result that gives you over a 20% increase in confidence, with only a one-character loss, and assume that the result with a threshold of 145 was simply incorrect, or perhaps split a character or found something that wasn't there.

This is the part where some upfront experimentation to perfect your threshold selection algorithm may come in handy. For instance, you may want to select the score for which the *product* of the confidence and the number of characters is maximized (in this case, 145 still wins with a product of 6272, and in our imaginary example, the threshold 150 would win with a product of 7964) or some other metric.

Note that this type of selection algorithm also works with arbitrary PIL tool values besides just `threshold`. Also, you can use it to select two or more values by varying the values of each and selecting the best resulting score in a similar way.

Obviously, this type of selection algorithm is computationally intensive. You're running both PIL and Tesseract many times on every single image, whereas if you know the "ideal" threshold values ahead of time, you have to run them only once.

Keep in mind that, as you start to work with the images that you're processing, you may start to notice patterns in the "ideal" values that are found. Instead of trying every threshold from 80 to 200, you may realistically need to try only thresholds from 130 to 180.

You may even take another approach and choose thresholds that are, say, 20 apart on the first pass, and then use a greedy algorithm to hone in on the best result by decreasing your step size for thresholds between the "best" solutions found in the previous iteration. This may also work best when you're dealing with multiple variables.

Scraping Text from Images on Websites

Using Tesseract to read text from an image on your hard drive might not seem all that exciting, but it can be a powerful tool when used with a web scraper. Images can inadvertently obfuscate text on websites (as with the JPG copy of a menu on a local restaurant site), but they can also purposefully hide the text, as I'll show in the next example.

Although Amazon's *robots.txt* file allows scraping of the site's product pages, book previews typically don't get picked up by passing bots. That's because the book previews are loaded via user-triggered Ajax scripts, and the images are carefully hidden under layers of divs. To the average site visitor, they probably look more like Flash presentations than image files. Of course, even if you could get to the images, there's the not-so-small matter of reading them as text.

The following script accomplishes just this feat: it navigates to the large-print edition[1] of Tolstoy's *The Death of Ivan Ilyich*, opens the reader, collects image URLs, and then systematically downloads, reads, and prints the text from each one.

Note that this code depends on a live Amazon listing as well as several architectural features of the Amazon website to run correctly. If this listing goes down or is replaced, please fill free to substitute the URL of another book with a Preview feature (I find that large-print, sans-serif fonts work well).

Because this is relatively complex code that draws on multiple concepts from previous chapters, I've added comments throughout to make it a little easier to understand what's going on:

```
import time
from urllib.request import urlretrieve
from PIL import Image
```

1 When it comes to processing text it hasn't been trained on, Tesseract fares much better with large-format editions of books, especially if the images are small. The next section covers how to train Tesseract on different fonts, which can help it read much smaller font sizes, including previews for non-large-print book editions!

```
import tesseract
from selenium import webdriver


def getImageText(imageUrl):
    urlretrieve(image, 'page.jpg')
    p = subprocess.Popen(['tesseract', 'page.jpg', 'page'],
        stdout=subprocess.PIPE,stderr=subprocess.PIPE)
    p.wait()
    f = open('page.txt', 'r')
    print(f.read())

#Create new Selenium driver
driver = webdriver.Chrome(executable_path='<Path to chromedriver>')

driver.get('https://www.amazon.com/Death-Ivan-Ilyich'\
    '-Nikolayevich-Tolstoy/dp/1427027277')
time.sleep(2)

#Click on the book preview button
driver.find_element_by_id('imgBlkFront').click()
imageList = []

#Wait for the page to load
time.sleep(5)

while 'pointer' in driver.find_element_by_id(
    'sitbReaderRightPageTurner').get_attribute('style'):
    # While the right arrow is available for clicking, turn through pages
    driver.find_element_by_id('sitbReaderRightPageTurner').click()
    time.sleep(2)
    # Get any new pages that have loaded (multiple pages can load at once,
    # but duplicates will not be added to a set)
    pages = driver.find_elements_by_xpath('//div[@class=\'pageImage\']/div/img')
    if not len(pages):
        print("No pages found")
    for page in pages:
        image = page.get_attribute('src')
        print('Found image: {}'.format(image))
        if image not in imageList:
            imageList.append(image)
            getImageText(image)

driver.quit()
```

Although this script can, in theory, be run with any type of Selenium webdriver, I've found that it currently works most reliably with Chrome.

As you have experienced with the Tesseract reader before, this prints many long passages of the book mostly legibly, as seen in the preview of the first chapter:

```
Chapter I
```

```
During an Interval In the Melvmskl trial In the large
building of the Law Courts the members and public
prosecutor met in [van Egorowch Shebek‘s private
room, where the conversation turned on the celebrated
Krasovski case. Fedor Vasillevich warmly maintained
that it was not subject to their jurisdiction, Ivan
Egorovich maintained the contrary, while Peter
ivanowch, not havmg entered into the discussmn at
the start, took no part in it but looked through the
Gazette which had Just been handed in.

“Gentlemen,” he said, “Ivan Ilych has died!"
```

However, many of the words have obvious errors, such as “Melvmsl” instead of the name “Melvinski” and “discussmn” instead of “discussion.” Many errors of this type can be fixed by making guesses based on a dictionary word list (perhaps with additions based on relevant proper nouns like “Melvinski”).

Occasionally an error may span an entire word, such as on page 3 of the text:

```
it is he who is dead and not 1.
```

In this case the word “I” is replaced by the character “1.” A Markov chain analysis might be useful here, in addition to a word dictionary. If any part of the text contains an extremely uncommon phrase (“and not 1”), it might be assumed that the text was actually the more common phrase (“and not I”).

Of course, it helps that these character substitutions follow predictable patterns: “vi” becomes “w,” and “I” becomes “1.” If these substitutions occur frequently in your text, you might create a list of them that can be used to “try” new words and phrases, selecting the solution that makes the most sense. An approach might be to substitute frequently confused characters, and use a solution that matches a word in a dictionary, or is a recognized (or most common) n-gram.

If you do take this approach, be sure to read Chapter 9 for more information about working with text and natural language processing.

Although the text in this example is a common sans-serif font and Tesseract should be able to recognize it with relative ease, sometimes a little retraining helps improve the accuracy as well. The next section discusses another approach to solving the problem of mangled text with a little upfront time investment.

By providing Tesseract with a large collection of text images with known values, Tesseract can be “taught” to recognize the same font in the future with far greater precision and accuracy, even despite occasional background and positioning problems in the text.

Reading CAPTCHAs and Training Tesseract

Although the word *CAPTCHA* is familiar to most, far fewer people know what it stands for: *Completely Automated Public Turing Test to Tell Computers and Humans Apart*. Its unwieldy acronym hints at its rather unwieldy role in obstructing otherwise perfectly usable web interfaces, as both humans and nonhuman robots often struggle to solve CAPTCHA tests.

The Turing test was first described by Alan Turing in his 1950 paper, "Computing Machinery and Intelligence." In the paper, he described a setup in which a human being could communicate with both humans and artificial intelligence programs through a computer terminal. If the human was unable to distinguish the humans from the AI programs during a casual conversation, the AI programs would be considered to have passed the Turing test, and the artificial intelligence, Turing reasoned, would be genuinely "thinking" for all intents and purposes.

It's ironic that in the last 60 years we've gone from using these tests to test machines to using them to test ourselves, with mixed results. Google recently killed off their notoriously difficult reCAPTCHA due in large part to its tendency to block legitimate website users.[2]

Most other CAPTCHAs are somewhat easier. Drupal, a popular PHP-based content management system, for example, has a popular CAPTCHA module that can generate CAPTCHA images of varying difficulty. The default image looks like Figure 13-4.

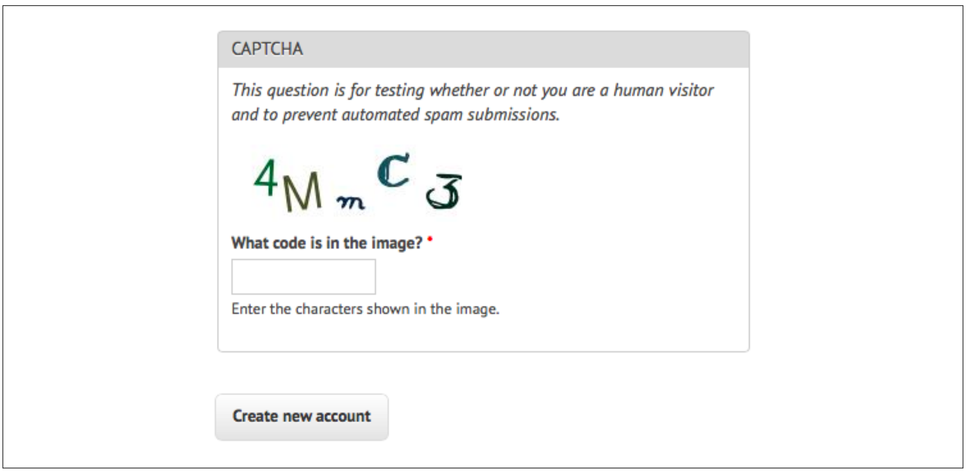


Figure 13-4. An example of the default text CAPTCHA for Drupal's CAPTCHA project

2 See *https://gizmodo.com/google-has-finally-killed-the-captcha-1793190374*.

What makes this CAPTCHA so easy for both humans and machines to read, compared to other CAPTCHAs?

- Characters do not overlap each other, nor do they cross into each other's space horizontally. That is, it is possible to draw a neat rectangle around each character without overlapping any other character.
- There are no background images, lines, or other distracting garbage that could confuse an OCR program.
- It is not obvious from this image, but there are few variations on the font that the CAPTCHA uses. It alternates between a clean sans-serif font (as seen in the characters "4" and "M") and a handwriting-style font (as seen in the characters "m," "C," and "3").
- There is high contrast between the white background and the dark-colored characters.

This CAPTCHA does throw a few curves, though, that make it challenging for OCR programs to read:

- Both letters and numbers are used, increasing the number of potential characters.
- The randomized tilt of the letters might confuse OCR software, but remains easy for humans to read.
- The relatively strange handwriting font presents particular challenges, with extra lines in the "C" and "3" and an unusually small lowercase "m" requiring extra training for computers to get the hang of.

When you run Tesseract over this image using the command

```
$ tesseract captchaExample.png output
```

you get this *output.txt* file:

```
4N\,,,C<3
```

It got the 4, C, and 3 right, but it's clearly not going to be able to fill out a CAPTCHA-protected field any time soon.

Training Tesseract

In order to train Tesseract to recognize writing, whether it's an obscure and difficult-to-read font or a CAPTCHA, you need to give it multiple examples of each character.

This is the part where you might want to queue up a good podcast or movie because it's going to be a couple of hours of fairly boring work. The first step is to download multiple examples of your CAPTCHA into a single directory. The number of examples you compile will depend on the complexity of the CAPTCHA; I used 100 sample

files (a total of 500 characters, or about 8 examples per symbol, on average) for my CAPTCHA training, and that seemed to work fairly well.

> I recommend naming the image after the CAPTCHA solution it represents (e.g., *4MmC3.jpg*). I've found that this helps to do quick error-checking across large numbers of files at once; you can view all files as thumbnails and compare the image against its image name easily. This helps greatly in error checking in subsequent steps, as well.

The second step is to tell Tesseract exactly what each character is and where it is in the image. This involves creating box files, one for every CAPTCHA image. A box file looks like this:

```
4 15 26 33 55 0
M 38 13 67 45 0
m 79 15 101 26 0
C 111 33 136 60 0
3 147 17 176 45 0
```

The first symbol is the character represented, the next four numbers represent coordinates for a rectangular box outlining the image, and the last number is a "page number" used for training with multipage documents (0 for us).

Obviously, these box files are not fun to create by hand, but a variety of tools can help you out. I like the online tool Tesseract OCR Chopper because it requires no installation or additional libraries, runs on any machine that has a browser, and is relatively easy to use. Upload the image, click the Add button at the bottom if you need additional boxes, adjust the size of the boxes if necessary, and copy and paste your new *.box* file text into a new file.

Box files must be saved in plain text, with the *.box* file extension. As with the image files, it's handy to name the box files by the CAPTCHA solutions they represent (e.g., *4MmC3.box*). Again, this makes it easy to double-check the contents of the *.box* file text against the name of the file, and then again against the image file it is paired with if you sort all the files in your data directory by their filenames.

Again, you'll need to create about 100 of these files to ensure that you have enough data. Also, Tesseract does occasionally discard files as being unreadable, so you might want some buffer room on top of that. If you find that your OCR results aren't quite as good as you'd like, or Tesseract is stumbling over certain characters, it's a good debugging step to create additional training data and try again.

After creating a data folder full of *.box* files and image files, copy this data into a backup folder before doing any further manipulation on it. Although running training scripts over the data is unlikely to delete anything, it's better safe than sorry when

hours' worth of work put into *.box* file creation is involved. Additionally, it's good to be able to scrap a messy directory full of compiled data and try again.

There are half a dozen steps to performing all the data analysis and creating the training files required for Tesseract. There are tools that do this for you given corresponding source image and *.box* files, but none at the moment for Tesseract 3.02, unfortunately.

I've written a solution in Python that operates over a file containing both image and box files and creates all necessary training files automatically.

The initial settings and steps that this program takes can be seen in the `__init__` and `runAll` methods of the class:

```
def __init__(self):
    languageName = 'eng'
    fontName = 'captchaFont'
    directory = '<path to images>'

def runAll(self):
    self.createFontFile()
    self.cleanImages()
    self.renameFiles()
    self.extractUnicode()
    self.runShapeClustering()
    self.runMfTraining()
    self.runCnTraining()
    self.createTessData()
```

The only three variables you'll need to set here are fairly straightforward:

`languageName`
: The three-letter language code that Tesseract uses to understand which language it's looking at. In most cases, you'll probably want to use `eng` for English.

`fontName`
: The name for your chosen font. This can be anything, but must be a single word without spaces.

`directory`
: The directory containing all your image and box files. I recommend you make this an absolute path, but if you use a relative path, it will need to be relative to where you are running the Python code from. If it is absolute, you can run the code from anywhere on your machine.

Let's take a look at the individual functions used.

`createFontFile` creates a required file, *font_properties*, that lets Tesseract know about the new font you are creating:

```
captchaFont 0 0 0 0 0
```

This file consists of the name of the font, followed by 1s and 0s indicating whether italic, bold, or other versions of the font should be considered. (Training fonts with these properties is an interesting exercise, but unfortunately outside the scope of this book.)

`cleanImages` creates higher-contrast versions of all image files found, converts them to grayscale, and performs other operations that make the image files easier to read by OCR programs. If you are dealing with CAPTCHA images with visual garbage that might be easy to filter out in postprocessing, here would be the place to add that additional processing.

`renameFiles` renames all your *.box* files and their corresponding image files with the names required by Tesseract (the file numbers here are sequential digits to keep multiple files separate):

- *<languageName>.<fontName>.exp<fileNumber>.box*
- *<languageName>.<fontName>.exp<fileNumber>.tiff*

`extractUnicode` looks at all of the created *.box* files and determines the total set of characters available to be trained. The resulting Unicode file will tell you how many different characters you've found, and could be a good way to quickly see if you're missing anything.

The next three functions, `runShapeClustering`, `runMfTraining`, and `runCtTraining`, create the files `shapetable`, `pfftable`, and `normproto`, respectively. These all provide information about the geometry and shape of each character, as well as provide statistical information that Tesseract uses to calculate the probability that a given character is one type or another.

Finally, Tesseract renames each of the compiled data folders to be prepended by the required language name (e.g., *shapetable* is renamed to *eng.shapetable*) and compiles all of those files into the final training data file *eng.traineddata*.

The only step you have to perform manually is move the created *eng.traineddata* file to your *tessdata* root folder by using the following commands on Linux and Mac:

```
$cp /path/to/data/eng.traineddata $TESSDATA_PREFIX/tessdata
```

Following these steps, you should have no problem solving CAPTCHAs of the type that Tesseract has now been trained for. Now when you ask Tesseract to read the example image, you get the correct response:

```
$ tesseract captchaExample.png output|cat output.txt
4MmC3
```

Success! A significant improvement over the previous interpretation of the image as `4N\,,,C<3`.

This is just a quick overview of the full power of Tesseract's font training and recognition capabilities. If you are interested in extensively training Tesseract, perhaps starting your own library of CAPTCHA training files, or sharing new font recognition capabilities with the world, I recommend checking out the documentation.

Retrieving CAPTCHAs and Submitting Solutions

Many popular content management systems are frequently spammed with registrations by bots that are preprogrammed with the well-known location of these user registration pages. On *http://pythonscraping.com*, for instance, even a CAPTCHA (admittedly, weak) does little to put a damper on the influx of registrations.

So how do these bots do it? We've successfully solved CAPTCHAs in images sitting around on our hard drive, but how do we make a fully functioning bot? This section ties together many techniques covered in previous chapters. If you haven't already, you should at least skim Chapter 10.

Most image-based CAPTCHAs have several properties:

- They are dynamically generated images, created by a server-side program. They might have image sources that do not look like traditional images, such as `<img src="WebForm.aspx?id=8AP85CQKE9TJ">`, but can be downloaded and manipulated like any other image.
- The solution to the image is stored in a server-side database.
- Many CAPTCHAs time out if you take too long to solve them. This usually isn't a problem for bots, but queuing CAPTCHA solutions for later use, or other practices that may delay the time between when the CAPTCHA was requested and when the solution is submitted, may not be successful.

The general approach to this is to download the CAPTCHA image file to your hard drive, clean it, use Tesseract to parse the image, and return the solution under the appropriate form parameter.

I've created a page at *http://pythonscraping.com/humans-only* with a CAPTCHA-protected comment form for the purpose of writing a bot to defeat. This bot uses the command line Tesseract library, rather than the pytesseract wrapper (although it could easily use either) and looks like the following:

```
from urllib.request import urlretrieve
from urllib.request import urlopen
from bs4 import BeautifulSoup
import subprocess
import requests
```

```
from PIL import Image
from PIL import ImageOps

def cleanImage(imagePath):
    image = Image.open(imagePath)
    image = image.point(lambda x: 0 if x<143 else 255)
    borderImage = ImageOps.expand(image,border=20,fill='white')
    borderImage.save(imagePath)

html = urlopen('http://www.pythonscraping.com/humans-only')
bs = BeautifulSoup(html, 'html.parser')
#Gather prepopulated form values
imageLocation = bs.find('img', {'title': 'Image CAPTCHA'})['src']
formBuildId = bs.find('input', {'name':'form_build_id'})['value']
captchaSid = bs.find('input', {'name':'captcha_sid'})['value']
captchaToken = bs.find('input', {'name':'captcha_token'})['value']

captchaUrl = 'http://pythonscraping.com'+imageLocation
urlretrieve(captchaUrl, 'captcha.jpg')
cleanImage('captcha.jpg')
p = subprocess.Popen(['tesseract', 'captcha.jpg', 'captcha'], stdout=
    subprocess.PIPE,stderr=subprocess.PIPE)
p.wait()
f = open('captcha.txt', 'r')

#Clean any whitespace characters
captchaResponse = f.read().replace(' ', '').replace('\n', '')
print('Captcha solution attempt: '+captchaResponse)

if len(captchaResponse) == 5:
    params = {'captcha_token':captchaToken, 'captcha_sid':captchaSid,
              'form_id':'comment_node_page_form', 'form_build_id': formBuildId,
              'captcha_response':captchaResponse, 'name':'Ryan Mitchell',
              'subject': 'I come to seek the Grail',
              'comment_body[und][0][value]':
               '...and I am definitely not a bot'}
    r = requests.post('http://www.pythonscraping.com/comment/reply/10',
                          data=params)
    responseObj = BeautifulSoup(r.text, 'html.parser')
    if responseObj.find('div', {'class':'messages'}) is not None:
        print(responseObj.find('div', {'class':'messages'}).get_text())
else:
    print('There was a problem reading the CAPTCHA correctly!')
```

Note that this script fails under two conditions: if Tesseract did not extract exactly five characters from the image (because you know that all valid solutions to this CAPTCHA must have five characters), or if it submits the form but the CAPTCHA was solved incorrectly. The first case happens approximately 50% of the time, at which point it does not bother submitting the form and fails with an error message. The second case happens approximately 20% of the time, for a total accuracy

rate of about 30% (or about 80% accuracy for each character encountered, over five characters).

Although this may seem low, keep in mind that usually no limit is placed on the number of times users are allowed to make CAPTCHA attempts, and that most of these incorrect attempts can be aborted without needing to actually send the form. When a form is sent, the CAPTCHA is accurate most of the time. If that doesn't convince you, also keep in mind that simple guessing would give you an accuracy rate of .0000001%. Running a program three or four times rather than guessing 900 million times is quite the time-saver!

CHAPTER 14
Avoiding Scraping Traps

Few things are more frustrating than scraping a site, viewing the output, and not seeing the data that's so clearly visible in your browser. Or submitting a form that should be perfectly fine but gets denied by the web server. Or getting your IP address blocked by a site for unknown reasons.

These are some of the most difficult bugs to solve, not only because they can be so unexpected (a script that works just fine on one site might not work at all on another, seemingly identical, site), but because they purposefully don't have any telltale error messages or stack traces to use. You've been identified as a bot, rejected, and you don't know why.

In this book, I've written about a lot of ways to do tricky things on websites (submitting forms, extracting and cleaning difficult data, executing JavaScript, etc.). This chapter is a bit of a catchall in that the techniques stem from a wide variety of subjects (HTTP headers, CSS, and HTML forms, to name a few). However, they all have something in common: they are meant to overcome an obstacle put in place for the sole purpose of preventing automated web scraping of a site.

Regardless of how immediately useful this information is to you at the moment, I highly recommend you at least skim this chapter. You never know when it might help you solve a difficult bug or prevent a problem altogether.

A Note on Ethics

In the first few chapters of this book, I discussed the legal gray area that web scraping inhabits, as well as some of the ethical guidelines to scrape by. To be honest, this chapter is, ethically, perhaps the most difficult one for me to write. My websites have been plagued by bots, spammers, web scrapers, and all manner of unwanted virtual guests, as perhaps yours have been. So why teach people how to build better bots?

I believe this chapter is important to include for a few reasons:

- There are perfectly ethical and legally sound reasons to scrape some websites that do not want to be scraped. In a previous job I had as a web scraper, I performed automated collection of information from websites that were publishing clients' names, addresses, telephone numbers, and other personal information to the internet without their consent. I used the scraped information to make formal requests to the websites to remove this information. In order to avoid competition, these sites guarded this information from scrapers vigilantly. However, my work to ensure the anonymity of my company's clients (some of whom had stalkers, were the victims of domestic violence, or had other very good reasons to want to keep a low profile) made a compelling case for web scraping, and I was grateful that I had the skills necessary to do the job.
- Although it is almost impossible to build a "scraper proof" site (or at least one that can still be easily accessed by legitimate users), I hope that the information in this chapter will help those wanting to defend their websites against malicious attacks. Throughout, I will point out some of the weaknesses in each web scraping technique, which you can use to defend your own site. Keep in mind that most bots on the web today are merely doing a broad scan for information and vulnerabilities, and employing even a couple of simple techniques described in this chapter will likely thwart 99% of them. However, they are getting more sophisticated every month, and it's best to be prepared.
- Like most programmers, I don't believe that withholding any sort of educational information is a net positive thing to do.

While you're reading this chapter, keep in mind that many of these scripts and described techniques should not be run against every site you can find. Not only is it not a nice thing to do, but you could wind up receiving a cease-and-desist letter or worse (for more information about what to do if you receive such a letter, see Chapter 18). But I'm not going to pound you over the head with this every time we discuss a new technique. So, for the rest of this chapter, as the philosopher Gump once said: "That's all I have to say about that."

Looking Like a Human

The fundamental challenge for sites that do not want to be scraped is figuring out how to tell bots from humans. Although many of the techniques sites use (such as CAPTCHAs) can be difficult to fool, you can do a few fairly easy things to make your bot look more human.

Adjust Your Headers

Throughout the book, you've used the Python *Requests* library to create, send, and receive HTTP requests, such as handling forms on a website in Chapter 10. The *Requests* library is also excellent for setting headers. HTTP headers are lists of attributes, or preferences, sent by you every time you make a request to a web server. HTTP defines dozens of obscure header types, most of which are not commonly used. The following seven fields, however, are consistently used by most major browsers when initiating any connection (shown with example data from my own browser):

`Host`	https://www.google.com/
`Connection`	keep-alive
`Accept`	text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,*/*;q=0.8
`User-Agent`	Mozilla/5.0 (Macintosh; Intel Mac OS X 10_9_5) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/39.0.2171.95 Safari/537.36
`Referrer`	https://www.google.com/
`Accept-Encoding`	gzip, deflate, sdch
`Accept-Language`	en-US,en;q=0.8

And here are the headers that a typical Python scraper using the default `urllib` library might send:

`Accept-Encoding`	identity
`User-Agent`	Python-urllib/3.4

If you're a website administrator trying to block scrapers, which one are you more likely to let through?

Fortunately, headers can be completely customized using the *Requests* library. The website *https://www.whatismybrowser.com* is great for testing browser properties viewable by servers. You'll scrape this website to verify your cookie settings with the following script:

```
import requests
from bs4 import BeautifulSoup

session = requests.Session()
headers = {'User-Agent':'Mozilla/5.0 (Macintosh; Intel Mac OS X 10_9_5)'
           'AppleWebKit 537.36 (KHTML, like Gecko) Chrome',
           'Accept':'text/html,application/xhtml+xml,application/xml;'
           'q=0.9,image/webp,*/*;q=0.8'}
url = 'https://www.whatismybrowser.com/'\
    'developers/what-http-headers-is-my-browser-sending'
req = session.get(url, headers=headers)
```

```
bs = BeautifulSoup(req.text, 'html.parser')
print(bs.find('table', {'class':'table-striped'}).get_text)
```

The output should show that the headers are now the same ones set in the `headers` dictionary object in the code.

Although it is possible for websites to check for "humanness" based on any of the properties in HTTP headers, I've found that typically the only setting that really matters is the `User-Agent`. It's a good idea to keep this one set to something more inconspicuous than `Python-urllib/3.4`, regardless of what project you are working on. In addition, if you ever encounter an extremely suspicious website, populating one of the commonly used but rarely checked headers such as `Accept-Language` might be the key to convincing it you're a human.

Headers Change the Way You See the World

Let's say you want to write a machine-learning language translator for a research project, but lack large amounts of translated text to test with. Many large sites present different translations of the same content, based on the indicated language preferences in your headers. Simply changing `Accept-Language:en-US` to `Accept-Language:fr` in your headers might get you a "Bonjour" from websites with the scale and budget to handle translation (large international companies are usually a good bet).

Headers also can prompt websites to change the format of the content they are presenting. For instance, mobile devices browsing the web often see a pared-down version of sites, lacking banner ads, Flash, and other distractions. If you try changing your `User-Agent` to something like the following, you might find that sites get a little easier to scrape!

```
User-Agent:Mozilla/5.0 (iPhone; CPU iPhone OS 7_1_2 like Mac OS X)
AppleWebKit/537.51.2 (KHTML, like Gecko) Version/7.0 Mobile/11D257
Safari/9537.53
```

Handling Cookies with JavaScript

Handling cookies correctly can alleviate many scraping problems, although cookies can also be a double-edged sword. Websites that track your progression through a site using cookies might attempt to cut off scrapers that display abnormal behavior, such as completing forms too quickly, or visiting too many pages. Although these behaviors can be disguised by closing and reopening connections to the site, or even changing your IP address (see Chapter 17 for more information on how to do that), if your cookie gives your identity away, your efforts of disguise might be futile.

Cookies can also be necessary to scrape a site. As shown in Chapter 10, staying logged in on a site requires that you be able to hold and present a cookie from page to page. Some websites don't even require that you actually log in and get a new version of a cookie every time—merely holding an old copy of a "logged-in" cookie and visiting the site is enough.

If you are scraping a single targeted website or a small number of targeted sites, I recommend examining the cookies generated by those sites and considering which ones you might want your scraper to handle. Various browser plug-ins can show you how cookies are being set as you visit and move around a site. EditThisCookie, a Chrome extension, is one of my favorites.

Check out the code samples in "Handling Logins and Cookies" on page 156 in Chapter 10 for more information about handling cookies by using the *Requests* library. Of course, because it is unable to execute JavaScript, the *Requests* library will be unable to handle many of the cookies produced by modern tracking software, such as Google Analytics, which are set only after the execution of client-side scripts (or sometimes based on page events, such as button clicks, that happen while browsing the page). To handle these, you need to use the Selenium and PhantomJS packages (we covered their installation and basic usage in Chapter 11).

You can view cookies by visiting any site (*http://pythonscraping.com*, in this example) and calling `get_cookies()` on the webdriver:

```
from selenium import webdriver
driver = webdriver.PhantomJS(executable_path='<Path to Phantom JS>')
driver.get('http://pythonscraping.com')
driver.implicitly_wait(1)
print(driver.get_cookies())
```

This provides the fairly typical array of Google Analytics cookies:

```
[{'value': '1', 'httponly': False, 'name': '_gat', 'path': '/', 'expi
ry': 1422806785, 'expires': 'Sun, 01 Feb 2015 16:06:25 GMT', 'secure'
: False, 'domain': '.pythonscraping.com'}, {'value': 'GA1.2.161952506
2.1422806186', 'httponly': False, 'name': '_ga', 'path': '/', 'expiry
': 1485878185, 'expires': 'Tue, 31 Jan 2017 15:56:25 GMT', 'secure':
False, 'domain': '.pythonscraping.com'}, {'value': '1', 'httponly': F
alse, 'name': 'has_js', 'path': '/', 'expiry': 1485878185, 'expires':
 'Tue, 31 Jan 2017 15:56:25 GMT', 'secure': False, 'domain': 'pythons
craping.com'}]
```

To manipulate cookies, you can call the `delete_cookie()`, `add_cookie()`, and `delete_all_cookies()` functions. In addition, you can save and store cookies for use in other web scrapers. Here's an example to give you an idea of how these functions work together:

```
from selenium import webdriver

phantomPath = '<Path to Phantom JS>'
```

```
driver = webdriver.PhantomJS(executable_path=phantomPath)
driver.get('http://pythonscraping.com')
driver.implicitly_wait(1)

savedCookies = driver.get_cookies()
print(savedCookies)

driver2 = webdriver.PhantomJS(executable_path=phantomPath)
driver2.get('http://pythonscraping.com')
driver2.delete_all_cookies()
for cookie in savedCookies:
    if not cookie['domain'].startswith('.'):
        cookie['domain'] = '.{}'.format(cookie['domain'])
    driver2.add_cookie(cookie)

driver2.get('http://pythonscraping.com')
driver.implicitly_wait(1)
print(driver2.get_cookies())
```

In this example, the first webdriver retrieves a website, prints the cookies, and then stores them in the variable `savedCookies`. The second webdriver loads the same website, deletes its own cookies, and adds the cookies from the first webdriver. A couple of technical notes here:

- The second webdriver must load the website first before the cookies are added. This is so Selenium knows which domain the cookies belong to, even if the act of loading the website does nothing useful for the scraper.
- A check is made before loading each cookie to see whether the domain starts with a period (.) character. This is a quirk of PhantomJS—all domains in added cookies must begin with a period (for example, `.pythonscraping.com`), even if not all the cookies in the PhantomJS webdriver actually follow this rule. If you are using another browser driver, such as Chrome or Firefox, you do not need to do this.

After this is done, the second webdriver should have the same cookies as the first. According to Google Analytics, this second webdriver is now identical to the first one, and they will be tracked in the same way. If the first webdriver was logged into a site, the second webdriver will be as well.

Timing Is Everything

Some well-protected websites might prevent you from submitting forms or interacting with the site if you do it too quickly. Even if these security features aren't in place, downloading lots of information from a website significantly faster than a normal human might is a good way to get yourself noticed, and blocked.

Therefore, although multithreaded programming might be a great way to load pages faster—allowing you to process data in one thread while repeatedly loading pages in another—it's a terrible policy for writing good scrapers. You should always try to keep individual page loads and data requests to a minimum. If possible, try to space them out by a few seconds, even if you have to add in an extra:

```python
import time

time.sleep(3)
```

Whether or not you need this extra few seconds between page loads is often found experimentally. Many times I've struggled to scrape data from a website, having to prove myself as "not a robot" every few minutes (solving the CAPTCHA by hand, pasting my newly obtained cookies back over to the scraper so the website viewed the scraper itself as having "proven its humanness"), but adding a `time.sleep` solved my problems and allowed me to scrape indefinitely.

Sometimes you have to slow down to go fast!

Common Form Security Features

Many litmus tests have been used over the years, and continue to be used, with varying degrees of success, to separate web scrapers from browser-using humans. Although it's not a big deal if a bot downloads some articles and blog posts that were available to the public anyway, it is a big problem if a bot creates thousands of user accounts and starts spamming all of your site's members. Web forms, especially forms that deal with account creation and logins, pose a significant threat to security and computational overhead if they're vulnerable to indiscriminate use by bots, so it's in the best interest of many site owners (or at least they think it is) to try to limit access to the site.

These antibot security measures centered on forms and logins can pose a significant challenge to web scrapers.

Keep in mind that this is only a partial overview of some of the security measures you might encounter when creating automated bots for these forms. Review Chapter 13, on dealing with CAPTCHAs and image processing, as well as Chapter 17, on dealing with headers and IP addresses, for more information on dealing with well-protected forms.

Hidden Input Field Values

"Hidden" fields in HTML forms allow the value contained in the field to be viewable by the browser but invisible to the user (unless they look at the site's source code). With the increase in use of cookies to store variables and pass them around on web-

sites, hidden fields fell out of a favor for a while before another excellent purpose was discovered for them: preventing scrapers from submitting forms.

Figure 14-1 shows an example of these hidden fields at work on a Facebook login page. Although the form has only three visible fields (Username, Password, and a Submit button), it conveys a great deal of information to the server behind the scenes.

Figure 14-1. The Facebook login form has quite a few hidden fields

Hidden fields are used to prevent web scraping in two main ways: a field can be populated with a randomly generated variable on the form page that the server is expecting to be posted to the form-processing page. If this value is not present in the form, the server can reasonably assume that the submission did not originate organically from the form page, but was posted by a bot directly to the processing page. The best way to get around this measure is to scrape the form page first, collect the randomly generated variable, and then post to the processing page from there.

The second method is a "honeypot" of sorts. If a form contains a hidden field with an innocuous name, such as Username or Email Address, a poorly written bot might fill out the field and attempt to submit it, regardless of whether it is hidden to the user. Any hidden fields with actual values (or values that are different from their defaults on the form submission page) should be disregarded, and the user may even be blocked from the site.

In short: It is sometimes necessary to check the page that the form is on to see whether you missed anything that the server might be expecting. If you see several hidden fields, often with large, randomly generated string variables, the web server likely will be checking for their existence on form submission. In addition, there might be other checks to ensure that the form variables have been used only once, are recently generated (this eliminates the possibility of simply storing them in a script and using them over and over again over time), or both.

Avoiding Honeypots

Although CSS for the most part makes life extremely easy when it comes to differentiating useful information from nonuseful information (e.g., by reading the `id` and `class` tags), it can occasionally be problematic for web scrapers. If a field on a web form is hidden from a user via CSS, it is reasonable to assume that the average user visiting the site will not be able to fill it out because it doesn't show up in the browser. If the form *is* populated, there is likely a bot at work and the post will be discarded.

This applies not only to forms but to links, images, files, and any other item on the site that can be read by a bot but is hidden from the average user visiting the site through a browser. A page visit to a "hidden" link on a site can easily trigger a server-side script that will block the user's IP address, log that user out of the site, or take some other action to prevent further access. In fact, many business models have been based on exactly this concept.

Take, for example, the page located at *http://pythonscraping.com/pages/itsatrap.html*. This page contains two links, one hidden by CSS and another visible. In addition, it contains a form with two hidden fields:

```
<html>
<head>
    <title>A bot-proof form</title>
</head>
<style>
    body {
        overflow-x:hidden;
    }
    .customHidden {
        position:absolute;
        right:50000px;
    }
</style>
<body>
    <h2>A bot-proof form</h2>
    <a href=
     "http://pythonscraping.com/dontgohere" style="display:none;">Go here!</a>
    <a href="http://pythonscraping.com">Click me!</a>
    <form>
        <input type="hidden" name="phone" value="valueShouldNotBeModified"/><p/>
        <input type="text" name="email" class="customHidden"
                  value="intentionallyBlank"/><p/>
        <input type="text" name="firstName"/><p/>
        <input type="text" name="lastName"/><p/>
        <input type="submit" value="Submit"/><p/>
   </form>
</body>
</html>
```

These three elements are hidden from the user in three ways:

- The first link is hidden with a simple CSS `display:none` attribute.
- The phone field is a hidden input field.
- The email field is hidden by moving it 50,000 pixels to the right (presumably off the screen of everyone's monitors) and hiding the telltale scroll bar.

Fortunately, because Selenium renders the pages it visits, it is able to distinguish between elements that are visually present on the page and those that aren't. Whether the element is present on the page can be determined by the `is_displayed()` function.

For example, the following code retrieves the previously described page and looks for hidden links and form input fields:

```
from selenium import webdriver
from selenium.webdriver.remote.webelement import WebElement

driver = webdriver.PhantomJS(executable_path='<Path to Phantom JS>')
driver.get('http://pythonscraping.com/pages/itsatrap.html')
links = driver.find_elements_by_tag_name('a')
for link in links:
    if not link.is_displayed():
        print('The link {} is a trap'.format(link.get_attribute('href')))

fields = driver.find_elements_by_tag_name('input')
for field in fields:
    if not field.is_displayed():
        print('Do not change value of {}'.format(field.get_attribute('name')))
```

Selenium catches each hidden field, producing the following output:

```
The link http://pythonscraping.com/dontgohere is a trap
Do not change value of phone
Do not change value of email
```

Although you probably don't want to visit any hidden links you find, you will want to make sure that you submit any prepopulated hidden form values (or have Selenium submit them for you) with the rest of the form. To sum up, it is dangerous to simply ignore hidden fields, although you must be careful when interacting with them.

The Human Checklist

There's a lot of information in this chapter, and indeed in this book, about how to build a scraper that looks less like a scraper and more like a human. If you keep getting blocked by websites and you don't know why, here's a checklist you can use to remedy the problem:

- First, if the page you are receiving from the web server is blank, missing information, or is otherwise not what you expect (or have seen in your own browser), it is likely caused by JavaScript being executed on the site to create the page. Review Chapter 11.
- If you are submitting a form or making a `POST` request to a website, check the page to make sure that everything the website is expecting you to submit is being submitted and in the correct format. Use a tool such as Chrome's Inspector panel to view an actual `POST` request sent to the site to make sure you have everything, and that an "organic" request looks the same as the ones your bot is sending.
- If you are trying to log into a site and can't make the login "stick," or the website is experiencing other strange "state" behavior, check your cookies. Make sure that cookies are being persisted correctly between each page load and that your cookies are sent to the site for every request.
- If you are getting HTTP errors from the client, especially 403 Forbidden errors, it might indicate that the website has identified your IP address as a bot and is unwilling to accept any more requests. You will need to either wait until your IP address is removed from the list, or obtain a new IP address (either move to a Starbucks or see Chapter 17). To make sure you don't get blocked again, try the following:
  — Make sure that your scrapers aren't moving through the site too quickly. Fast scraping is a bad practice that places a heavy burden on the web administrator's servers, can land you in legal trouble, and is the number-one cause of scrapers getting blacklisted. Add delays to your scrapers and let them run overnight. Remember: Being in a rush to write programs or gather data is a sign of bad project management; plan ahead to avoid messes like this in the first place.
  — The obvious one: change your headers! Some sites will block anything that advertises itself as a scraper. Copy your own browser's headers if you're unsure about what some reasonable header values are.
  — Make sure you're not clicking on or accessing anything that a human normally would not be able to (refer to "Avoiding Honeypots" on page 223 for more information).
  — If you find yourself jumping through a lot of difficult hoops to gain access, consider contacting the website administrator to let them know what you're doing. Try emailing *webmaster@<domain name>* or *admin@<domain name>* for permission to use your scrapers. Admins are people too, and you might be surprised at how amenable they can be to sharing their data.

CHAPTER 15
Testing Your Website with Scrapers

When working with web projects that have a large development stack, it's often only the "back" of the stack that ever gets tested regularly. Most programming languages today (including Python) have some type of test framework, but website frontends are often left out of these automated tests, although they might be the only customer-facing part of the project.

Part of the problem is that websites are often a mishmash of many markup languages and programming languages. You can write unit tests for sections of your JavaScript, but it's useless if the HTML it's interacting with has changed in such a way that the JavaScript doesn't have the intended action on the page, even if it's working correctly.

The problem of frontend website testing has often been left as an afterthought, or delegated to lower-level programmers armed with, at most, a checklist and a bug tracker. However, with just a little more upfront effort, you can replace this checklist with a series of unit tests, and replace human eyes with a web scraper.

Imagine: test-driven development for web development. Daily tests to make sure all parts of the web interface are functioning as expected. A suite of tests run every time someone adds a new website feature, or changes the position of an element. This chapter covers the basics of testing and how to test all sorts of websites, from simple to complicated, with Python-based web scrapers.

An Introduction to Testing

If you've never written tests for your code before, there's no better time to start than now. Having a suite of tests that can be run to ensure that your code performs as expected (at least, as far as you've written tests for) saves you time and worry and makes releasing new updates easy.

What Are Unit Tests?

The words *test* and *unit test* are often used interchangeably. Often, when programmers refer to "writing tests," what they really mean is "writing unit tests." On the other hand, when some programmers refer to writing unit tests, they're really writing some other kind of test.

Although definitions and practices tend to vary from company to company, a unit test generally has the following characteristics:

- Each unit test tests one aspect of the functionality of a component. For example, it might ensure that the appropriate error message is thrown if a negative number of dollars is withdrawn from a bank account.

  Often, unit tests are grouped together in the same class, based on the component they are testing. You might have the test for a negative dollar value being withdrawn from a bank account, followed by a unit test for the behavior of an overdrawn bank account.
- Each unit test can be run completely independently, and any setup or teardown required for the unit test must be handled by the unit test itself. Similarly, unit tests must not interfere with the success or failure of other tests, and they must be able to run successfully in any order.
- Each unit test usually contains at least one *assertion*. For example, a unit test might assert that the answer to 2 + 2 is 4. Occasionally, a unit test might contain only a failure state. For example, it might fail if an exception is thrown, but pass by default if everything goes smoothly.
- Unit tests are separated from the bulk of the code. Although they necessarily need to import and use the code they are testing, they are generally kept in separate classes and directories.

Although many other types of tests can be written—integration tests and validation tests, for example—this chapter primarily focuses on unit testing. Not only have unit tests become extremely popular, with recent pushes toward test-driven development, but their length and flexibility make them easy to work with as examples, and Python has some built-in unit testing capabilities, as you'll see in the next section.

Python unittest

Python's unit-testing module, `unittest`, comes packaged with all standard Python installations. Just import and extend `unittest.TestCase`, and it will do the following:

- Provide `setUp` and `tearDown` functions that run before and after each unit test
- Provide several types of "assert" statements to allow tests to pass or fail

- Run all functions that begin with `test_` as unit tests, and ignore functions that are not prepended as tests

The following provides a simple unit test for ensuring that 2 + 2 = 4, according to Python:

```
import unittest

class TestAddition(unittest.TestCase):
    def setUp(self):
        print('Setting up the test')

    def tearDown(self):
        print('Tearing down the test')

    def test_twoPlusTwo(self):
        total = 2+2
        self.assertEqual(4, total);

if __name__ == '__main__':
    unittest.main()
```

Although `setUp` and `tearDown` don't provide any useful functionality here, they are included for the purposes of illustration. Note that these functions are run before and after each individual test, not before and after all the tests in the class.

The output of the test function, when run from the command line, should look like this:

```
Setting up the test
Tearing down the test
.
----------------------------------------------------------------------
Ran 1 test in 0.000s

OK
```

This indicates that the test ran successfully, and 2 + 2 does indeed equal 4.

Running unittest in Jupyter Notebooks

The unit test scripts in this chapter are all kicked off with:

```
if __name__ == '__main__':
    unittest.main()
```

The line if `__name__ == '__main__'` is true only if the line is executed directly in Python, and not via an import statement. This allows you to run your unit test, using the `unittest.TestCase` class that it extends, directly from the command line.

In a Jupyter notebook, things are a little bit different. The `argv` parameters created by Jupyter can cause errors in the unit test, and, because the `unittest` framework exits Python by default after the test is run (which causes problems in the notebook kernel), we also need to prevent that from happening.

In the Jupyter notebooks, you will use the following to launch unit tests:

```
if __name__ == '__main__':
    unittest.main(argv=[''], exit=False)
    %reset
```

The second line sets all of the `argv` variables (command-line arguments) to a single empty string, which is ignored by `unittest.main`. It also prevents `unittest` from exiting after the test is run.

The `%reset` line is useful because it resets the memory and destroys all user-created variables in the Jupyter notebook. Without it, each unit test you write in the notebook will contain all of the methods from all other previously run tests that also inherited `unittest.TestCase`, including `setUp` and `tearDown` methods. This also means that each unit test would run all of the methods from the unit tests before it!

Using `%reset` does create one extra manual step for the user when running the tests. When running the test, the notebook will prompt the user and ask if they're sure they want to reset the memory. Simply type **`y`** and hit Enter to do this.

Testing Wikipedia

Testing the frontend of your website (excluding JavaScript, which we'll cover next) is as simple as combining the Python `unittest` library with a web scraper:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import unittest

class TestWikipedia(unittest.TestCase):
    bs = None
    def setUpClass():
        url = 'http://en.wikipedia.org/wiki/Monty_Python'
        TestWikipedia.bs = BeautifulSoup(urlopen(url), 'html.parser')

    def test_titleText(self):
        pageTitle = TestWikipedia.bs.find('h1').get_text()
        self.assertEqual('Monty Python', pageTitle);

    def test_contentExists(self):
        content = TestWikipedia.bs.find('div',{'id':'mw-content-text'})
        self.assertIsNotNone(content)
```

```
if __name__ == '__main__':
    unittest.main()
```

There are two tests this time: the first tests whether the title of the page is the expected "Monty Python," and the second makes sure that the page has a content div.

Note that the content of the page is loaded only once, and that the global object `bs` is shared between tests. This is accomplished by using the `unittest`-specified function `setUpClass`, which is run only once at the start of the class (unlike `setUp`, which is run before every individual test). Using `setUpClass` instead of `setUp` saves unnecessary page loads; you can grab the content once and run multiple tests on it.

One major architectural difference between `setUpClass` and `setUp`, besides just when and how often they're run, is that `setUpClass` is a static method that "belongs" to the class itself and has global class variables, whereas `setUp` is an instance function that belongs to a particular instance of the class. This is why `setUp` can set attributes on `self`—the particular instance of that class—while `setUpClass` can access only static class attributes on the class `TestWikipedia`.

Although testing a single page at a time might not seem all that powerful or interesting, as you may recall from Chapter 3, it is relatively easy to build web crawlers that can iteratively move through all pages of a website. What happens when you combine a web crawler with a unit test that makes an assertion about each page?

There are many ways to run a test repeatedly, but you must be careful to load each page only once for each set of tests you want to run on the page, and you must also avoid holding large amounts of information in memory at once. The following setup does just that:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import unittest
import re
import random
from urllib.parse import unquote

class TestWikipedia(unittest.TestCase):

    def test_PageProperties(self):
        self.url = 'http://en.wikipedia.org/wiki/Monty_Python'
        #Test the first 10 pages we encounter
        for i in range(1, 10):
            self.bs = BeautifulSoup(urlopen(self.url), 'html.parser')
            titles = self.titleMatchesURL()
            self.assertEquals(titles[0], titles[1])
            self.assertTrue(self.contentExists())
            self.url = self.getNextLink()
        print('Done!')
```

```
    def titleMatchesURL(self):
        pageTitle = self.bs.find('h1').get_text()
        urlTitle = self.url[(self.url.index('/wiki/')+6):]
        urlTitle = urlTitle.replace('_', ' ')
        urlTitle = unquote(urlTitle)
        return [pageTitle.lower(), urlTitle.lower()]

    def contentExists(self):
        content = self.bs.find('div',{'id':'mw-content-text'})
        if content is not None:
            return True
        return False

    def getNextLink(self):
        #Returns random link on page, using technique from Chapter 3
        links = self.bs.find('div', {'id':'bodyContent'}).find_all(
            'a', href=re.compile('^(/wiki/)((?!:).)*$'))
        randomLink = random.SystemRandom().choice(links)
        return 'https://wikipedia.org{}'.format(randomLink.attrs['href'])

if __name__ == '__main__':
    unittest.main()
```

There are a few things to notice. First, there is only one actual test in this class. The other functions are technically only helper functions, even though they're doing the bulk of the computational work to determine whether a test passes. Because the test function performs the assertion statements, the results of the test are passed back to the test function where the assertions happen.

Also, while `contentExists` returns a boolean, `titleMatchesURL` returns the values themselves back for evaluation. To see why you would want to pass values back rather than just a boolean, compare the results of a boolean assertion:

```
======================================================================
FAIL: test_PageProperties (__main__.TestWikipedia)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "15-3.py", line 22, in test_PageProperties
    self.assertTrue(self.titleMatchesURL())
AssertionError: False is not true
```

with the results of an `assertEquals` statement:

```
======================================================================
FAIL: test_PageProperties (__main__.TestWikipedia)
----------------------------------------------------------------------
Traceback (most recent call last):
  File "15-3.py", line 23, in test_PageProperties
    self.assertEquals(titles[0], titles[1])
AssertionError: 'lockheed u-2' != 'u-2 spy plane'
```

Which one is easier to debug? (In this case, the error is occurring because of a redirect, when the article *http://wikipedia.org/wiki/u-2%20spy%20plane* redirects to an article titled "Lockheed U-2.")

Testing with Selenium

As with Ajax scraping in Chapter 11, JavaScript presents particular challenges when doing website testing. Fortunately, Selenium has an excellent framework in place for handling particularly complicated websites; in fact, the library was originally designed for website testing!

Although obviously written in the same language, the syntax of Python unit tests and Selenium unit tests have surprisingly little in common. Selenium does not require that its unit tests be contained as functions within classes; its `assert` statements do not require parentheses; and tests pass silently, producing some kind of message only on a failure:

```
driver = webdriver.PhantomJS()
driver.get('http://en.wikipedia.org/wiki/Monty_Python')
assert 'Monty Python' in driver.title
driver.close()
```

When run, this test should produce no output.

In this way, Selenium tests can be written more casually than Python unit tests, and `assert` statements can even be integrated into regular code, where it is desirable for code execution to terminate if some condition is not met.

Interacting with the Site

Recently, I wanted to contact a local small business through its website's contact form but found that the HTML form was broken; nothing happened when I clicked the submit button. After a little investigation, I saw they were using a simple mailto form that was designed to send them an email with the form's contents. Fortunately, I was able to use this information to send them an email, explain the problem with their form, and hire them, despite the technical issue.

If I were to write a traditional scraper that used or tested this form, my scraper would likely just copy the layout of the form and send an email directly—bypassing the form altogether. How could I test the functionality of the form and ensure that it was working perfectly through a browser?

Although previous chapters have discussed navigating links, submitting forms, and other types of interaction-like activity, at its core everything we've done is designed to *bypass* the browser interface, not use it. Selenium, on the other hand, can literally enter text, click buttons, and do everything through the browser (in this case, the

headless PhantomJS browser), and detect things like broken forms, badly coded JavaScript, HTML typos, and other issues that might stymie actual customers.

Key to this sort of testing is the concept of Selenium `elements`. This object was briefly encountered in Chapter 11, and is returned by calls like this:

```
usernameField = driver.find_element_by_name('username')
```

Just as there are numerous actions you can take on various elements of a website in your browser, there are many actions Selenium can perform on any given element. Among these are the following:

```
myElement.click()
myElement.click_and_hold()
myElement.release()
myElement.double_click()
myElement.send_keys_to_element('content to enter')
```

In addition to performing a one-time action on an element, strings of actions can be combined into *action chains*, which can be stored and executed once or multiple times in a program. Action chains are useful in that they can be a convenient way to string long sets of multiple actions, but they are functionally identical to calling the action explicitly on the element, as in the preceding examples.

To see this difference, take a look at the form page at *http://pythonscraping.com/pages/files/form.html* (which was previously used as an example in Chapter 10). We can fill out the form and submit it in the following way:

```
from selenium import webdriver
from selenium.webdriver.remote.webelement import WebElement
from selenium.webdriver.common.keys import Keys
from selenium.webdriver import ActionChains


driver = webdriver.PhantomJS(executable_path='<Path to Phantom JS>')
driver.get('http://pythonscraping.com/pages/files/form.html')

firstnameField = driver.find_element_by_name('firstname')
lastnameField = driver.find_element_by_name('lastname')
submitButton = driver.find_element_by_id('submit')

### METHOD 1 ###
firstnameField.send_keys('Ryan')
lastnameField.send_keys('Mitchell')
submitButton.click()
################

### METHOD 2 ###
actions = ActionChains(driver).click(firstnameField).send_keys('Ryan')
                              .click(lastnameField).send_keys('Mitchell')
                              .send_keys(Keys.RETURN)
actions.perform()
```

```
################

print(driver.find_element_by_tag_name('body').text)

driver.close()
```

Method 1 calls `send_keys` on the two fields and then clicks the submit button. Method 2 uses a single action chain to click and enter text in each field, which happens in a sequence after the `perform` method is called. This script operates in the same way, whether the first method or the second method is used, and prints this line:

```
Hello there, Ryan Mitchell!
```

There is another variation in the two methods, in addition to the objects they use to handle the commands: notice that the first method clicks the Submit button, while the second uses the Return keystroke to submit the form while the text box is submitted. Because there are many ways to think about the sequence of events that complete the same action, there are many ways to complete the same action using Selenium.

Drag and drop

Clicking buttons and entering text is one thing, but where Selenium really shines is in its ability to deal with relatively novel forms of web interaction. Selenium allows for the manipulation of drag-and-drop interfaces with ease. Using its drag-and-drop function requires you to specify a *source* element (the element to be dragged) and either an offset to drag it across, or a target element to drag it to.

The demo page located at *http://pythonscraping.com/pages/javascript/draggableDemo.html* presents an example of this type of interface:

```
from selenium import webdriver
from selenium.webdriver.remote.webelement import WebElement
from selenium.webdriver import ActionChains

driver = webdriver.PhantomJS(executable_path='<Path to Phantom JS>')
driver.get('http://pythonscraping.com/pages/javascript/draggableDemo.html')

print(driver.find_element_by_id('message').text)

element = driver.find_element_by_id('draggable')
target = driver.find_element_by_id('div2')
actions = ActionChains(driver)
actions.drag_and_drop(element, target).perform()

print(driver.find_element_by_id('message').text)
```

Two messages are printed out from the `message` div on the demo page. The first says

```
Prove you are not a bot, by dragging the square from the blue area to the red
area!
```

Then, quickly, after the task is completed, the content is printed out again, which now reads

```
You are definitely not a bot!
```

As the demo page suggests, dragging elements to prove you're not a bot is a common theme in many CAPTCHAs. Although bots have been able to drag objects around for a long time (it's just a matter of clicking, holding, and moving), somehow the idea of using "drag this" as a verification of humanity just won't die.

In addition, these draggable CAPTCHA libraries rarely use any difficult-for-bots tasks, like "drag the picture of the kitten onto the picture of the cow" (which requires you to identify the pictures as "a kitten" and "a cow," while parsing instructions); instead, they often involve number ordering or some other fairly trivial task like the one in the preceding example.

Of course, their strength lies in the fact that there are so many variations, and they are so infrequently used; no one will likely bother making a bot that can defeat all of them. At any rate, this example should be enough to illustrate why you should never use this technique for large-scale websites.

Taking screenshots

In addition to the usual testing capabilities, Selenium has an interesting trick up its sleeve that might make your testing (or impressing your boss) a little easier: screenshots. Yes, photographic evidence can be created from unit tests run without the need for actually pressing the PrtScn key:

```
driver = webdriver.PhantomJS()
driver.get('http://www.pythonscraping.com/')
driver.get_screenshot_as_file('tmp/pythonscraping.png')
```

This script navigates to *http://pythonscraping.com* and then stores a screenshot of the home page in the local *tmp* folder (the folder must already exist for this to store correctly). Screenshots can be saved as a variety of image formats.

unittest or Selenium?

The syntactical rigor and verboseness of Python `unittest` might be desirable for most large test suites, while the flexibility and power of a Selenium test might be your only option for testing some website features. So which to use?

Here's the secret: you don't have to choose. Selenium can easily be used to obtain information about a website, and `unittest` can evaluate whether that information meets the criteria for passing the test. There is no reason you can't import Selenium tools into Python `unittest`, combining the best of both worlds.

For example, the following script creates a unit test for a website's draggable interface, asserting that it correctly says, "You are not a bot!" after one element has been dragged to another:

```
from selenium import webdriver
from selenium.webdriver.remote.webelement import WebElement
from selenium.webdriver import ActionChains
import unittest

class TestDragAndDrop(unittest.TestCase):
    driver = None
    def setUp(self):
        self.driver = webdriver.PhantomJS(executable_path='<Path to PhantomJS>')
        url = 'http://pythonscraping.com/pages/javascript/draggableDemo.html'
        self.driver.get(url)

    def tearDown(self):
        print("Tearing down the test")

    def test_drag(self):
        element = self.driver.find_element_by_id('draggable')
        target = self.driver.find_element_by_id('div2')
        actions = ActionChains(self.driver)
        actions.drag_and_drop(element, target).perform()
        self.assertEqual('You are definitely not a bot!',
            self.driver.find_element_by_id('message').text)

if __name__ == '__main__':
    unittest.main(argv=[''], exit=False)
```

Virtually anything on a website can be tested with the combination of Python's `unittest` and Selenium. In fact, combined with some of the image-processing libraries from Chapter 13, you can even take a screenshot of the website and test on a pixel-by-pixel basis what it should contain!

CHAPTER 16

Web Crawling in Parallel

Web crawling is fast. At least, it's usually much faster than hiring a dozen interns to copy data from the internet by hand! Of course, the progression of technology and the hedonic treadmill demand that at a certain point even this will not be "fast enough." That's the point at which people generally start to look toward distributed computing.

Unlike most other technology fields, web crawling cannot often be improved simply by "throwing more cycles at the problem." Running one process is fast; running two processes is not necessarily twice as fast. Running three processes might get you banned from the remote server you're hammering on with all your requests!

However, in some situations parallel web crawling, or running parallel threads/processes, can still be of benefit:

- Collecting data from multiple sources (multiple remote servers) instead of just a single source
- Performing long/complex operations on the collected data (such as doing image analysis or OCR) that could be done in parallel with fetching the data
- Collecting data from a large web service where you are paying for each query, or where creating multiple connections to the service is within the bounds of your usage agreement

Processes versus Threads

Python supports both multiprocessing and multithreading. Both multiprocessing and multithreading achieve the same ultimate goal: performing two programming tasks at the same time instead of running the program in a more traditional linear way.

In computer science, each process running on an operating system can have multiple threads. Each process has its own allocated memory, which means that multiple threads can access that same memory, while multiple processes cannot and must communicate information explicitly.

Using multithreaded programming to execute tasks in separate threads with shared memory is often considered easier than multiprocess programming. But this convenience comes at a cost.

Python's global interpreter lock (or GIL) acts to prevent threads from executing the same line of code at once. The GIL ensures that the common memory shared by all processes does not become corrupted (for instance, bytes in memory being half written with one value and half written with another value). This locking makes it possible to write a multithreaded program and know what you're getting, within the same line, but it also has the potential to create bottlenecks.

Multithreaded Crawling

Python 3.x uses the `_thread` module; the `thread` module is deprecated.

The following example illustrates using multiple threads to perform a task:

```
import _thread
import time

def print_time(threadName, delay, iterations):
    start = int(time.time())
    for i in range(0,iterations):
        time.sleep(delay)
        seconds_elapsed = str(int(time.time()) - start)
        print ("{} {}".format(seconds_elapsed, threadName))

try:
    _thread.start_new_thread(print_time, ('Fizz', 3, 33))
    _thread.start_new_thread(print_time, ('Buzz', 5, 20))
    _thread.start_new_thread(print_time, ('Counter', 1, 100))
except:
    print ('Error: unable to start thread')

while 1:
    pass
```

This is a reference to the classic FizzBuzz programming test, with a somewhat more verbose output:

```
1 Counter
2 Counter
3 Fizz
3 Counter
4 Counter
```

```
5 Buzz
5 Counter
6 Fizz
6 Counter
```

The script starts three threads, one that prints "Fizz" every three seconds, another that prints "Buzz" every five seconds, and a third that prints "Counter" every second.

After the threads are launched, the main execution thread hits a `while 1` loop that keeps the program (and its child threads) executing until the user hits Ctrl-C to stop execution.

Rather than printing fizzes and buzzes, you can perform a useful task in the threads, such as crawling a website:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re
import random

import _thread
import time

def get_links(thread_name, bs):
    print('Getting links in {}'.format(thread_name))
    return bs.find('div', {'id':'bodyContent'}).find_all('a',
        href=re.compile('^(/wiki/)((?!:).)*$'))

# Define a function for the thread
def scrape_article(thread_name, path):
    html = urlopen('http://en.wikipedia.org{}'.format(path))
    time.sleep(5)
    bs = BeautifulSoup(html, 'html.parser')
    title = bs.find('h1').get_text()
    print('Scraping {} in thread {}'.format(title, thread_name))
    links = get_links(thread_name, bs)
    if len(links) > 0:
        newArticle = links[random.randint(0, len(links)-1)].attrs['href']
        print(newArticle)
        scrape_article(thread_name, newArticle)


# Create two threads as follows
try:
   _thread.start_new_thread(scrape_article, ('Thread 1', '/wiki/Kevin_Bacon',))
   _thread.start_new_thread(scrape_article, ('Thread 2', '/wiki/Monty_Python',))
except:
   print ('Error: unable to start threads')

while 1:
    pass
```

Note the inclusion of this line:

```
time.sleep(5)
```

Because you are crawling Wikipedia almost twice as fast as you would with just a single thread, the inclusion of this line prevents the script from putting too much of a load on Wikipedia's servers. In practice, when running against a server where the number of requests is not an issue, this line should be removed.

What if you want to rewrite this slightly to keep track of the articles the threads have collectively seen so far, so that no article is visited twice? You can use a list in a multithreaded environment in the same way that you use it in a single-threaded environment:

```
visited = []
def get_links(thread_name, bs):
    print('Getting links in {}'.format(thread_name))
    links = bs.find('div', {'id':'bodyContent'}).find_all('a',
        href=re.compile('^(/wiki/)((?!:).)*$'))
    return [link for link in links if link not in visited]

def scrape_article(thread_name, path):
    visited.append(path)
```

Note that you are appending the path to the list of visited paths as the first action that `scrape_article` takes. This reduces, but does not entirely eliminate, the chances that it will be scraped twice.

If you are unlucky, both threads might still stumble across the same path at the same instant, both will see that it is not in the visited list, and both will subsequently add it to the list and scrape at the same time. However, in practice this is unlikely to happen because of the speed of execution and the number of pages that Wikipedia contains.

This is an example of a *race condition*. Race conditions can be tricky to debug, even for experienced programmers, so it is important to evaluate your code for these potential situations, estimate their likelihood, and anticipate the seriousness of their impact.

In the case of this particular race condition, where the scraper goes over the same page twice, it may not be worth writing around.

Race Conditions and Queues

Although you can communicate between threads with lists, lists are not specifically designed for communication between threads, and their misuse can easily cause slow program execution or even errors resulting from race conditions.

Lists are great for appending to or reading from, but not so great for removing items at arbitrary points, especially from the beginning of the list. Using a line like

```
myList.pop(0)
```

actually requires Python to rewrite the entire list, slowing program execution.

More dangerous, lists also make it convenient to accidentally write in a line that isn't thread-safe. For instance

```
myList[len(myList)-1]
```

may not actually get you the last item in the list in a multithreaded environment, or it may even throw an exception if the value for `len(myList)-1` is calculated immediately before another operation modifies the list.

One might argue that the preceding statement can be more "Pythonically" written as `myList[-1]`, and of course, no one has *ever* accidentally written non-Pythonic code in a moment of weakness (especially not Java developers thinking back to their days of patterns like `myList[myList.length-1]`)! But even if your code is beyond reproach, consider these other forms of non-thread-safe lines involving lists:

```
my_list[i] = my_list[i] + 1
my_list.append(my_list[-1])
```

Both of these may result in a race condition that can cause unexpected results. So let's abandon lists and pass messages to threads using nonlist variables!

```
# Read the message in from the global list
my_message = global_message
# Write a message back
global_message = 'I've retrieved the message'
# do something with my_message
```

That seems nice until you realize that you might have inadvertently overwritten another message coming in from another thread, in the instant between the first and second lines, with the text "I've got your message." So now you just need to construct an elaborate series of personal message objects for each thread with some logic to figure out who gets what...or you could use the `Queue` module built for this exact purpose.

Queues are list-like objects that operate on either a First In First Out (FIFO) approach or a Last In First Out (LIFO) approach. A queue receives messages from any thread via `queue.put('My message')` and can transmit the message to any thread that calls `queue.get()`.

Queues are not designed to store static data, but to transmit it in a thread-safe way. After it's retrieved from the queue, it should exist only in the thread that retrieved it. For this reason, they are commonly used to delegate tasks or send temporary notifications.

This can be useful in web crawling. For instance, let's say that you want to persist the data collected by your scraper into a database, and you want each thread to be able to

persist its data quickly. A single shared connection for all threads might cause issues (a single connection cannot handle requests in parallel), but it makes no sense to give every single scraping thread its own database connection. As your scraper grows in size (you may be collecting data from a hundred different websites in a hundred different threads eventually), this might translate into a lot of mostly idle database connections doing only an occasional write after a page loads.

Instead, you can have a smaller number of database threads, each with its own connection, sitting around taking items from a queue and storing them. This provides a much more manageable set of database connections.

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re
import random
import _thread
from queue import Queue
import time
import pymysql

def storage(queue):
    conn = pymysql.connect(host='127.0.0.1', unix_socket='/tmp/mysql.sock',
        user='root', passwd='', db='mysql', charset='utf8')
    cur = conn.cursor()
    cur.execute('USE wiki_threads')
    while 1:
        if not queue.empty():
            article = queue.get()
            cur.execute('SELECT * FROM pages WHERE path = %s',
                (article["path"]))
            if cur.rowcount == 0:
                print("Storing article {}".format(article["title"]))
                cur.execute('INSERT INTO pages (title, path) VALUES (%s, %s)', \
                    (article["title"], article["path"]))
                conn.commit()
            else:
                print("Article already exists: {}".format(article['title']))

visited = []
def getLinks(thread_name, bs):
    print('Getting links in {}'.format(thread_name))
    links = bs.find('div', {'id':'bodyContent'}).find_all('a',
        href=re.compile('^(/wiki/)((?!:).)*$'))
    return [link for link in links if link not in visited]

def scrape_article(thread_name, path, queue):
    visited.append(path)
    html = urlopen('http://en.wikipedia.org{}'.format(path))
    time.sleep(5)
    bs = BeautifulSoup(html, 'html.parser')
    title = bs.find('h1').get_text()
```

```
        print('Added {} for storage in thread {}'.format(title, thread_name))
        queue.put({"title":title, "path":path})
        links = getLinks(thread_name, bs)
        if len(links) > 0:
            newArticle = links[random.randint(0, len(links)-1)].attrs['href']
            scrape_article(thread_name, newArticle, queue)

queue = Queue()
try:
    _thread.start_new_thread(scrape_article, ('Thread 1',
        '/wiki/Kevin_Bacon', queue,))
    _thread.start_new_thread(scrape_article, ('Thread 2',
        '/wiki/Monty_Python', queue,))
    _thread.start_new_thread(storage, (queue,))
except:
    print ('Error: unable to start threads')

while 1:
    pass
```

This script creates three threads: two to scrape pages from Wikipedia in a random walk, and a third to store the collected data in a MySQL database. For more information about MySQL and data storage, see Chapter 6.

The threading Module

The Python `_thread` module is a fairly low-level module that allows you to micromanage your threads but doesn't provide a lot of higher-level functions that make life easier. The `threading` module is a higher-level interface that allows you to use threads cleanly while still exposing all of the features of the underlying `_thread`.

For example, you can use static functions like `enumerate` to get a list of all active threads initialized through the `threading` module without needing to keep track of them yourself. The `activeCount` function, similarly, provides the total number of threads. Many functions from _thread are given more convenient or memorable names, like `currentThread` instead of `get_ident` to get the name of the current thread.

This is a simple threading example:

```
import threading
import time

def print_time(threadName, delay, iterations):
    start = int(time.time())
    for i in range(0,iterations):
        time.sleep(delay)
        seconds_elapsed = str(int(time.time()) - start)
        print ('{} {}'.format(seconds_elapsed, threadName))
```

```
threading.Thread(target=print_time, args=('Fizz', 3, 33)).start()
threading.Thread(target=print_time, args=('Buzz', 5, 20)).start()
threading.Thread(target=print_time, args=('Counter', 1, 100)).start()
```

It produces the same "FizzBuzz" output as the previous simple `_thread` example.

One of the nice things about the threading module is the ease of creating local thread data that is unavailable to the other threads. This might be a nice feature if you have several threads, each scraping a different website, and each keeping track of its own local list of visited pages.

This local data can be created at any point within the thread function by calling `threading.local()`:

```
import threading

def crawler(url):
    data = threading.local()
    data.visited = []
    # Crawl site

threading.Thread(target=crawler, args=('http://brookings.edu')).start()
```

This solves the problem of race conditions happening between shared objects in threads. Whenever an object does not need to be shared it should not be, and should be kept in local thread memory. To safely share objects between threads the `Queue` from the previous section can still be used.

The threading module acts as a thread babysitter as sorts, and can be highly customized to define what that babysitting entails. The `isAlive` function by default looks to see if the thread is still active. It will be true until a thread completes crawling (or crashes).

Often, crawlers are designed to run for a very long time. The `isAlive` method can ensure that, if a thread crashes, it restarts:

```
threading.Thread(target=crawler)
t.start()

while True:
    time.sleep(1)
    if not t.isAlive():
        t = threading.Thread(target=crawler)
        t.start()
```

Other monitoring methods can be added by extending the `threading.Thread` object:

```
import threading
import time

class Crawler(threading.Thread):
```

```
    def __init__(self):
        threading.Thread.__init__(self)
        self.done = False

    def isDone(self):
        return self.done

    def run(self):
        time.sleep(5)
        self.done = True
        raise Exception('Something bad happened!')

t = Crawler()
t.start()

while True:
    time.sleep(1)
    if t.isDone():
        print('Done')
        break
    if not t.isAlive():
        t = Crawler()
        t.start()
```

This new Crawler class contains an `isDone` method that can be used to check if the crawler is done crawling. This may be useful if there are some additional logging methods that need to be finished so the thread cannot close, but the bulk of the crawling work is done. In general, `isDone` can be replaced with some sort of status or progress measure—how many pages logged, or the current page, for example.

Any exceptions raised by `Crawler.run` will cause the class to be restarted until `isDone` is `True` and the program exits.

Extending `threading.Thread` in your crawler classes can improve their robustness and flexibility, as well as your ability to monitor any property of many crawlers at once.

Multiprocess Crawling

The Python `Processing` module creates new process objects that can be started and joined from the main process. The following code uses the FizzBuzz example from the section on threading processes to demonstrate.

```
from multiprocessing import Process
import time

def print_time(threadName, delay, iterations):
    start = int(time.time())
    for i in range(0,iterations):
        time.sleep(delay)
```

```
        seconds_elapsed = str(int(time.time()) - start)
        print (threadName if threadName else seconds_elapsed)


processes = []
processes.append(Process(target=print_time, args=('Counter', 1, 100)))
processes.append(Process(target=print_time, args=('Fizz', 3, 33)))
processes.append(Process(target=print_time, args=('Buzz', 5, 20)))

for p in processes:
    p.start()
for p in processes:
    p.join()
```

Remember that each process is treated as an individual independent program by the OS. If you view your processes through your OS's activity monitor or task manager, you should see this reflected, as shown in Figure 16-1.

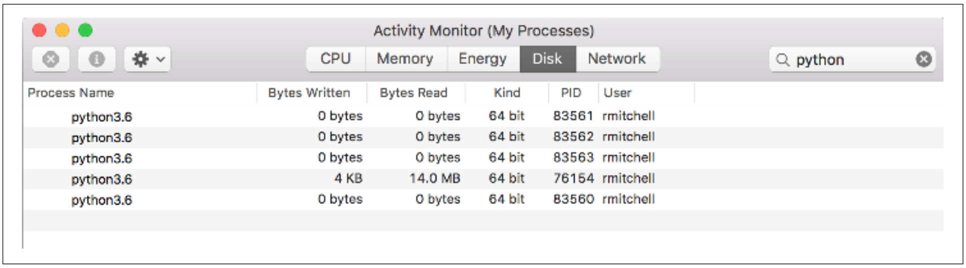


Figure 16-1. Five Python processes running while running FizzBuzz

The fourth process with PID 76154 is a running Jupyter notebook instance, which should appear if you are running this from the iPython notebook. The fifth process, 83560, is the main thread of execution, which starts up when the program is first executed. The PIDs are allocated by the OS sequentially. Unless you happen to have another program that quickly allocates a PID while the FizzBuzz script is running, you should see three more sequential PIDs—in this case 83561, 83562, and 83563.

These PIDs can also be found in code by using the `os` module:

```
import os
...
# prints the child PID
os.getpid()
# prints the parent PID
os.getppid()
```

Each process in your program should print a different PID for the line `os.getpid()`, but will print the same parent PID on `os.getppid()`.

Technically, there are a couple lines of code that are not needed for this particular program. If the ending join statement is not included

```
for p in processes:
    p.join()
```

the parent process will still end and terminate the child processes with it automatically. However, this joining is needed if you wish to execute any code after these child processes complete.

For example:

```
for p in processes:
    p.start()
print('Program complete')
```

If the join statement is not included, the output will be as follows:

```
Program complete
1
2
```

If the join statement is included, the program waits for each of the processes to finish before continuing:

```
for p in processes:
    p.start()

for p in processes:
    p.join()
print('Program complete')
```

```
...
Fizz
99
Buzz
100
Program complete
```

If you want to stop program execution prematurely, you can of course use Ctrl-C to terminate the parent process. The termination of the parent process will also terminate any child processes that have been spawned, so using Ctrl-C is safe to do without worrying about accidentally leaving processes running in the background.

Multiprocess Crawling

The multithreaded Wikipedia crawling example can be modified to use separate processes rather than separate threads:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re
import random

from multiprocessing import Process
import os
```

```
import time

visited = []
def get_links(bs):
    print('Getting links in {}'.format(os.getpid()))
    links = bs.find('div', {'id':'bodyContent'}).find_all('a',
        href=re.compile('^(/wiki/)((?!:).)*$'))
    return [link for link in links if link not in visited]

def scrape_article(path):
    visited.append(path)
    html = urlopen('http://en.wikipedia.org{}'.format(path))
    time.sleep(5)
    bs = BeautifulSoup(html, 'html.parser')
    title = bs.find('h1').get_text()
    print('Scraping {} in process {}'.format(title, os.getpid()))
    links = get_links(bs)
    if len(links) > 0:
        newArticle = links[random.randint(0, len(links)-1)].attrs['href']
        print(newArticle)
        scrape_article(newArticle)

processes = []
processes.append(Process(target=scrape_article, args=('/wiki/Kevin_Bacon',)))
processes.append(Process(target=scrape_article, args=('/wiki/Monty_Python',)))

for p in processes:
    p.start()
```

Again, you are artificially slowing the process of the scraper by including a `time.sleep(5)` so that this can be used for example purposes without placing an unreasonably high load on Wikipedia's servers.

Here, you are replacing the user-defined `thread_name`, passed around as an argument, with `os.getpid()`, which does not need to be passed as an argument and can be accessed at any point.

This produces output like the following:

```
Scraping Kevin Bacon in process 84275
Getting links in 84275
/wiki/Philadelphia
Scraping Monty Python in process 84276
Getting links in 84276
/wiki/BBC
Scraping BBC in process 84276
Getting links in 84276
/wiki/Television_Centre,_Newcastle_upon_Tyne
Scraping Philadelphia in process 84275
```

Crawling in separate processes is, in theory, slightly faster than crawling in separate threads for two major reasons:

- Processes are not subject to locking by the GIL and can execute the same lines of code and modify the same (really, separate instantiations of the same) object at the same time.
- Processes can run on multiple CPU cores, which may provide speed advantages if each of your processes or threads is processor intensive.

However, these advantages come with one major disadvantage. In the preceding program, all found URLs are stored in a global `visited` list. When you were using multiple threads, this list was shared among all threads; and one thread, in the absence of a rare race condition, could not visit a page that had already been visited by another thread. However, each process now gets its own independent version of the visited list and is free to visit pages that have already been visited by other processes.

Communicating Between Processes

Processes operate in their own independent memory, which can cause problems if you want them to share information.

Modifying the previous example to print the current output of the visited list, you can see this principle in action:

```
def scrape_article(path):
    visited.append(path)
    print("Process {} list is now: {}".format(os.getpid(), visited))
```

This results in output like the following:

```
Process 84552 list is now: ['/wiki/Kevin_Bacon']
Process 84553 list is now: ['/wiki/Monty_Python']
Scraping Kevin Bacon in process 84552
Getting links in 84552
/wiki/Desert_Storm
Process 84552 list is now: ['/wiki/Kevin_Bacon', '/wiki/Desert_Storm']
Scraping Monty Python in process 84553
Getting links in 84553
/wiki/David_Jason
Process 84553 list is now: ['/wiki/Monty_Python', '/wiki/David_Jason']
```

But there is a way to share information between processes on the same machine through two types of Python objects: queues and pipes.

A *queue* is similar to the threading queue seen previously. Information can be put into it by one process and removed by another process. After this information has been removed, it's gone from the queue. Because queues are designed as a method of "temporary data transmission," they're not well suited to hold a static reference such as a "list of webpages that have already been visited."

But what if this static list of web pages was replaced with some sort of a scraping delegator? The scrapers could pop off a task from one queue in the form of a path to scrape (for example, */wiki/Monty_Python*) and in return, add a list of "found URLs" back onto a separate queue that would be processed by the scraping delegator so that only new URLs were added to the first task queue:

```
from urllib.request import urlopen
from bs4 import BeautifulSoup
import re
import random
from multiprocessing import Process, Queue
import os
import time


def task_delegator(taskQueue, urlsQueue):
    #Initialize with a task for each process
    visited = ['/wiki/Kevin_Bacon', '/wiki/Monty_Python']
    taskQueue.put('/wiki/Kevin_Bacon')
    taskQueue.put('/wiki/Monty_Python')

    while 1:
        # Check to see if there are new links in the urlsQueue
        # for processing
        if not urlsQueue.empty():
            links = [link for link in urlsQueue.get() if link not in visited]
            for link in links:
                #Add new link to the taskQueue
                taskQueue.put(link)

def get_links(bs):
    links = bs.find('div', {'id':'bodyContent'}).find_all('a',
        href=re.compile('^(/wiki/)((?!:).)*$'))
    return [link.attrs['href'] for link in links]

def scrape_article(taskQueue, urlsQueue):
    while 1:
        while taskQueue.empty():
            #Sleep 100 ms while waiting for the task queue
            #This should be rare
            time.sleep(.1)
        path = taskQueue.get()
        html = urlopen('http://en.wikipedia.org{}'.format(path))
        time.sleep(5)
        bs = BeautifulSoup(html, 'html.parser')
        title = bs.find('h1').get_text()
        print('Scraping {} in process {}'.format(title, os.getpid()))
        links = get_links(bs)
        #Send these to the delegator for processing
        urlsQueue.put(links)
```

```
processes = []
taskQueue = Queue()
urlsQueue = Queue()
processes.append(Process(target=task_delegator, args=(taskQueue, urlsQueue,)))
processes.append(Process(target=scrape_article, args=(taskQueue, urlsQueue,)))
processes.append(Process(target=scrape_article, args=(taskQueue, urlsQueue,)))

for p in processes:
    p.start()
```

Some structural differences exist between this scraper and the ones originally created. Rather than each process or thread following its own random walk from the starting point they were assigned, they work together to do a complete coverage crawl of the website. Each process can pull any "task" from the queue, not just links that they have found themselves.

Multiprocess Crawling—Another Approach

All of the approaches discussed for multithreaded and multiprocess crawling assume that you require some sort of "parental guidance" over the child threads and processes. You can start them all at once, you can end them all at once, and you can send messages or share memory between them.

But what if your scraper is designed in such a way that no guidance or communication is required? There may be very little reason to start going crazy with `import _thread` just yet.

For example, let's say you want to crawl two similar websites in parallel. You have a crawler written that can crawl either of these websites, determined by a small configuration change or perhaps a command-line argument. There's absolutely no reason you can't simply do the following:

```
$ python my_crawler.py website1
```

```
$ python my_crawler.py website2
```

And voilà, you've just kicked off a multiprocess web crawler, while saving your CPU the overhead of keeping around a parent process to boot!

Of course, this approach has downsides. If you want to run two web crawlers on the *same* website in this way, you need some way of ensuring that they won't accidentally start scraping the same pages. The solution might be to create a URL rule ("crawler 1 scrapes the blog pages, crawler 2 scrapes the product pages") or divide the site in some way.

Alternatively, you may be able to handle this coordination through some sort of intermediate database. Before going to a new link, the crawler may make a request to the database to ask, "Has this page been crawled?" The crawler is using the database as an

interprocess communication system. Of course, without careful consideration, this method may lead to race conditions or lag if the database connection is slow (likely only a problem if connecting to a remote database).

You may also find that this method isn't quite as scalable. Using the `Process` module allows you to dynamically increase or decrease the number of processes crawling the site, or even storing data. Kicking them off by hand requires either a person physically running the script or a separate managing script (whether a bash script, a cron job, or something else) doing this.

However, this is a method I have used with great success in the past. For small, one-off projects, it is a great way to get a lot of information quickly, especially across multiple websites.

CHAPTER 17

Scraping Remotely

In the last chapter, you looked at running web scrapers across multiple threads and processes, where communication between them was somewhat limited or had to be carefully planned. This chapter brings this concept to its logical conclusion—running crawlers not just in separate processes, but on entirely separate machines.

That this chapter is the last in the book is somewhat appropriate. Until now you have been running all the Python applications from the command line, within the confines of your home computer. Sure, you might have installed MySQL in an attempt to replicate the environment of a real-life server. But it's just not the same. As the saying goes: "If you love something, set it free."

This chapter covers several methods for running scripts from different machines, or even just different IP addresses on your own machine. Although you might be tempted to put this step off as something you don't *need* right now, you might be surprised at how easy it is to get started with the tools you already have (such as a personal website on a paid hosting account), and how much easier your life becomes when you stop trying to run Python scrapers from your laptop.

Why Use Remote Servers?

Although using a remote server might seem like an obvious step when launching a web app intended for use by a wide audience, more often than not the tools we build for our own purposes are left running locally. People who decide to push onto a remote platform usually base their decision on two primary motivations: the need for greater power and flexibility, and the need to use an alternative IP address.

Avoiding IP Address Blocking

When building web scrapers, the rule of thumb is: almost everything can be faked. You can send emails from addresses you don't own, automate mouse-movement data from a command line, or even horrify web administrators by sending their website traffic from Internet Explorer 5.0.

The one thing that cannot be faked is your IP address. Anyone can send you a letter with the return address: "The President, 1600 Pennsylvania Avenue Northwest, Washington, DC 20500." However, if the letter is postmarked from Albuquerque, NM, you can be fairly certain you're not corresponding with the President of the United States.[1]

Most efforts to stop scrapers from accessing websites focus on detecting the difference between humans and bots. Going so far as to block IP addresses is a little like a farmer giving up spraying pesticides in favor of just torching the field. It's a last-ditch but effective method of discarding packets sent from troublesome IP addresses. However, there are problems with this solution:

- IP address access lists are painful to maintain. Although large websites most often have their own programs automating some of the routine management of these lists (bots blocking bots!), someone has to occasionally check them, or at least monitor their growth for problems.
- Each address adds a tiny amount of processing time to receive packets, as the server must check received packets against the list to decide whether to approve them. Many addresses multiplied by many packets can add up quickly. To save on processing time and complexity, admins often group these IP addresses into blocks and make rules such as "all 256 addresses in this range are blocked" if there are a few tightly clustered offenders. Which leads us to the third point.
- IP address blocking can lead to blocking the "good guys" as well. For example, while I was an undergrad at Olin College of Engineering, one student wrote some software that attempted to rig votes for popular content on *http://digg.com* (this was before Reddit was in vogue). A single blocked IP address led to an entire dormitory being unable to access the site. The student simply moved his software to another server; in the meantime, Digg lost page visits from many regular users in its prime target demographic.

1 Technically, IP addresses can be spoofed in outgoing packets, which is a technique used in distributed denial-of-service attacks, where the attackers don't care about receiving return packets (which, if sent, will be sent to the wrong address). But web scraping is by definition an activity in which a response from the web server is required, so we think of IP addresses as one thing that can't be faked.

Despite its drawbacks, IP address blocking remains an extremely common method for server administrators to stop suspected web scrapers from accessing servers. If an IP address is blocked, the only real solution is to scrape from a different IP address. This can be accomplished by moving the scraper to a new server or routing your traffic through a different server using a service such as Tor.

Portability and Extensibility

Some tasks are too large for a home computer and internet connection. Although you don't want to put a large load on any single website, you might be collecting data across a wide range of sites, and require a lot more bandwidth and storage than your current setup can provide.

Moreover, by offloading computationally intensive processing, you can free up your home machine's cycles for more important tasks (*World of Warcraft*, anyone?). You don't have to worry about maintaining power and an internet connection (launch your app at a Starbucks, pack up your laptop, and leave, knowing that everything's still running safely), and you can access your collected data anywhere there's an internet connection.

If you have an application that requires so much computing power that a single Amazon extra-large computing instance won't satisfy you, you can also look into *distributed computing*. This allows multiple machines to work in parallel to accomplish your goals. As a simple example, you might have one machine crawl one set of sites and another crawl a second set of sites, and have both of them store collected data in the same database.

Of course, as noted in previous chapters, many can replicate what Google search does, but few can replicate the scale at which Google search does it. Distributed computing is a large field of computer science that is outside the scope of this book. However, learning how to launch your application onto a remote server is a necessary first step, and you might be surprised at what computers are capable of these days.

Tor

The Onion Router network, better known by the acronym *Tor*, is a network of volunteer servers set up to route and reroute traffic through many layers (hence the onion reference) of different servers in order to obscure its origin. Data is encrypted before it enters the network so that if any particular server is eavesdropped on, the nature of the communication cannot be revealed. In addition, although the inbound and outbound communications of any particular server can be compromised, one would need to know the details of inbound and outbound communication for *all* the servers along the path of communication in order to decipher the true start and endpoints of a communication—a near-impossible feat.

Tor is commonly used by human rights workers and political whistleblowers to communicate with journalists, and receives much of its funding from the US government. Of course, it is also commonly used for illegal activities as well, and so remains a constant target for government surveillance (although to date, the surveillance has had only mixed success).

Limitations of Tor Anonymity

Although the reason you are using Tor in this book is to change your IP address, not achieve complete anonymity per se, it is worth taking a moment to address some of the strengths and limitations of Tor's ability to anonymize traffic.

Although you can assume when using Tor that the IP address you are coming from, according to a web server, is not an IP address that can be traced back to you, any information you share with that web server might expose you. For instance, if you log into your own Gmail account and then make incriminating Google searches, those searches can now be tied back to your identity.

Beyond the obvious, however, even the act of logging into Tor might be hazardous to your anonymity. In December 2013, a Harvard undergraduate student, in an attempt to get out of final exams, emailed a bomb threat to the school through the Tor network, using an anonymous email account. When the Harvard IT team looked at their logs, they found traffic going out to the Tor network from only a single machine, registered to a known student, during the time that the bomb threat was sent. Although they could not identify the eventual destination of this traffic (only that it was sent across Tor), the fact that the times matched up and only a single machine was logged in at the time was damning enough to prosecute the student.

Logging into Tor is not an automatic invisibility cloak, nor does it give you free reign to do as you please on the internet. Although it is a useful tool, be sure to use it with caution, intelligence, and, of course, morality.

Having Tor installed and running is a requirement for using Python with Tor, as you will see in the next section. Fortunately, the Tor service is extremely easy to install and start running with. Just go to the Tor downloads page and download, install, open, and connect! Keep in mind that your internet speed might appear to be slower while using Tor. Be patient—it might be going around the world several times!

PySocks

PySocks is a remarkably simple Python module that is capable of routing traffic through proxy servers and that works fantastically in conjunction with Tor. You can download it from its website or use any number of third-party module managers to install it.

Although not much in the way of documentation exists for this module, using it is extremely straightforward. The Tor service must be running on port 9150 (the default port) while running this code:

```
import socks
import socket
from urllib.request import urlopen

socks.set_default_proxy(socks.SOCKS5, "localhost", 9150)
socket.socket = socks.socksocket
print(urlopen('http://icanhazip.com').read())
```

The website *http://icanhazip.com* displays only the IP address for the client connecting to the server and can be useful for testing purposes. When this script is run, it should display an IP address that is not your own.

If you want to use Selenium and PhantomJS with Tor, you don't need PySocks at all—just make sure that Tor is currently running and add the optional `service_args` parameters, specifying that Selenium should connect through port 9150:

```
from selenium import webdriver
service_args = [ '--proxy=localhost:9150', '--proxy-type=socks5', ]
driver = webdriver.PhantomJS(executable_path='<path to PhantomJS>',
                             service_args=service_args)

driver.get('http://icanhazip.com')
print(driver.page_source)
driver.close()
```

Again, this should print out an IP address that is not your own but the one that your running Tor client is currently using.

Remote Hosting

Although complete anonymity is lost after you pull out your credit card, hosting your web scrapers remotely may dramatically improve their speed. This is both because you're able to purchase time on much larger machines than you likely own, but also because the connection no longer has to bounce through layers of a Tor network in order to reach its destination.

Running from a Website-Hosting Account

If you have a personal or business website, you might already likely have the means to run your web scrapers from an external server. Even with relatively locked-down web servers, where you have no access to the command line, it is possible to trigger scripts to start and stop through a web interface.

If your website is hosted on a Linux server, the server likely already runs Python. If you're hosting on a Windows server, you might be out of luck; you'll need to check specifically to see if Python is installed, or if the server administrator is willing to install it.

Most small web-hosting providers come with software called *cPanel*, used to provide basic administration services and information about your website and related services. If you have access to cPanel, you can make sure that Python is set up to run on your server by going to Apache Handlers and adding a new handler (if it is not already present):

```
Handler: cgi-script
Extension(s): .py
```

This tells your server that all Python scripts should be executed as a *CGI-script*. CGI, which stands for *Common Gateway Interface*, is any program that can be run on a server and dynamically generate content that is displayed on a website. By explicitly defining Python scripts as CGI scripts, you're giving the server permission to execute them, rather than just display them in a browser or send the user a download.

Write your Python script, upload it to the server, and set the file permissions to 755 to allow it to be executed. To execute the script, navigate to the place you uploaded it to through your browser (or even better, write a scraper to do it for you). If you're worried about the general public accessing and executing the script, you have two options:

- Store the script at an obscure or hidden URL and make sure to never link to the script from any other accessible URL to avoid search engines indexing it.
- Protect the script with a password, or require that a password or secret token be sent to it before it can execute.

Of course, running a Python script from a service that is specifically designed to display websites is a bit of a hack. For instance, you'll probably notice that your web scraper-cum-website is a little slow to load. In fact, the page doesn't actually load (complete with the output of all `print` statements you might have written in) until the entire scrape is complete. This might take minutes, hours, or never complete at all, depending on how it is written. Although it certainly gets the job done, you might want more real-time output. For that, you'll need a server that's designed for more than just the web.

Running from the Cloud

Back in the olden days of computing, programmers paid for or reserved time on computers in order to execute their code. With the advent of personal computers, this became unnecessary—you simply write and execute code on your own computer. Now, the ambitions of the applications have outpaced the development of the microprocessor to such a degree that programmers are once again moving to pay-per-hour computing instances.

This time around, however, users aren't paying for time on a single, physical machine but on its equivalent computing power, often spread among many machines. The nebulous structure of this system allows computing power to be priced according to times of peak demand. For instance, Amazon allows for bidding on "spot instances" when low costs are more important than immediacy.

Compute instances are also more specialized, and can be selected based on the needs of your application, with options like "high memory," "fast computing," and "large storage." Although web scrapers don't usually use much in the way of memory, you may want to consider large storage or fast computing in lieu of a more general-purpose instance for your scraping application. If you're doing large amounts of natural language processing, OCR work, or path finding (such as with the Six Degrees of Wikipedia problem), a fast computing instance might work well. If you're scraping large amounts of data, storing files, or doing large-scale analytics, you might want to go for an instance with storage optimization.

Although the sky is the limit as far as spending goes, at the time of this writing, instances start at just 1.3 cents an hour (for an Amazon EC2 micro instance), and Google's cheapest instance is 4.5 cents an hour, with a minimum of just 10 minutes. Thanks to the economies of scale, buying a small compute instance with a large company is about the same as buying your own physical, dedicated machine—except that now, you don't need to hire an IT guy to keep it running.

Of course, step-by-step instructions for setting up and running cloud computing instances are somewhat outside the scope of this book, but you will likely find that step-by-step instructions are not needed. With both Amazon and Google (not to mention the countless smaller companies in the industry) vying for cloud computing dollars, they've made setting up new instances as easy as following a simple prompt, thinking of an app name, and providing a credit card number. As of this writing, both Amazon and Google also offer hundreds of dollars' worth of free computing hours to further tempt new clients.

Once you have an instance set up, you should be the proud new owner of an IP address, username, and public/private keys that can be used to connect to your instance through SSH. From there, everything should be the same as working with a

server that you physically own—except, of course, you no longer have to worry about hardware maintenance or running your own plethora of advanced monitoring tools.

For quick and dirty jobs, especially if you don't have a lot of experience dealing with SSH and key pairs, I've found that Google's Cloud Platform instances can be easier to get up and running right away. They have a simple launcher and even have a button available after launch to view an SSH terminal right in the browser, as shown in Figure 17-1.

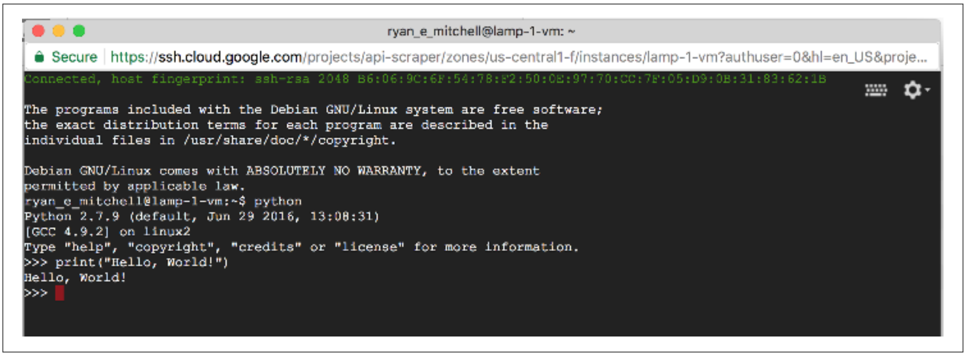


Figure 17-1. Browser-based terminal from a running Google Cloud Platform VM instance

Additional Resources

Many years ago, running "in the cloud" was mostly the domain of those who felt like slogging through the documentation and already had some server administration experience. However, today, the tools have improved dramatically, due to increased popularity and competition among cloud computing providers.

Still, for building large-scale or more-complex scrapers and crawlers, you might want a little more guidance on creating a platform for collecting and storing data.

Google Compute Engine by Marc Cohen, Kathryn Hurley, and Paul Newson (O'Reilly) is a straightforward resource on using Google Cloud Computing with both Python and JavaScript. Not only does it cover Google's user interface, but also the command-line and scripting tools that you can use to give your application greater flexibility.

If you prefer to work with Amazon, Mitch Garnaat's *Python and AWS Cookbook* (O'Reilly) is a brief but extremely useful guide that will get you started with Amazon Web Services and show you how to get a scalable application up and running.

CHAPTER 18

The Legalities and Ethics of Web Scraping

In 2010, software engineer Pete Warden built a web crawler to gather data from Facebook. He collected data from approximately 200 million Facebook users—names, location information, friends, and interests. Of course, Facebook noticed and sent him cease-and-desist letters, which he obeyed. When asked why he complied with the cease and desist, he said: "Big data? Cheap. Lawyers? Not so cheap."

In this chapter, you'll look at US laws (and some international ones) that are relevant to web scraping, and learn how to analyze the legality and ethics of a given web scraping situation.

Before you read this section, consider the obvious: I am a software engineer, not a lawyer. Do not interpret anything you read here or in any other chapter of the book as professional legal advice or act on it accordingly. Although I believe I'm able to discuss the legalities and ethics of web scraping knowledgeably, you should consult a lawyer (not a software engineer) before undertaking any legally ambiguous web scraping projects.

The goal of this chapter is to provide you with a framework for being able to understand and discuss various aspects of web scraping legalities, such as intellectual property, unauthorized computer access, and server usage, but should not be a substitute for actual legal advice.

Trademarks, Copyrights, Patents, Oh My!

Time for some Intellectual Property 101! There are three basic types of IP: trademarks (indicated by a ™ or ® symbol), copyrights (the ubiquitous ©), and patents (sometimes indicated by text noting that the invention is patent protected or a patent number, but often by nothing at all).

Patents are used to declare ownership over inventions only. You cannot patent images, text, or any information itself. Although some patents, such as software patents, are less tangible than what we think of as "inventions," keep in mind that it is the *thing* (or technique) that is patented—not the information contained in the patent. Unless you are either building things from scraped blueprints, or someone patents a method of web scraping, you are unlikely to inadvertently infringe on a patent by scraping the web.

Trademarks also are unlikely to be an issue, but still something that must be considered. According to the US Patent and Trademark Office:

> A *trademark* is a word, phrase, symbol, and/or design that identifies and distinguishes the source of the goods of one party from those of others. A *service mark* is a word, phrase, symbol, and/or design that identifies and distinguishes the source of a service rather than goods. The term "trademark" is often used to refer to both trademarks and service marks.

In addition to the traditional words/symbols branding that we think of when we think of trademarks, other descriptive attributes can be trademarked. This includes, for example, the shape of a container (think Coca-Cola bottles) or even a color (most notably, the pink color of Owens Corning's Pink Panther fiberglass insulation).

Unlike with patents, the ownership of a trademark depends heavily on the context in which it is used. For example, if I wish to publish a blog post with an accompanying picture of the Coca-Cola logo, I could do that (as long as I wasn't implying that my blog post was sponsored by, or published by, Coca-Cola). If I wanted to manufacture a new soft drink with the same Coca-Cola logo displayed on the packaging, that would clearly be a trademark infringement. Similarly, although I could package my new soft drink in Pink Panther pink, I could not use that same color to create a home insulation product.

Copyright Law

Both trademarks and patents have something in common in that they have to be formally registered in order to be recognized. Contrary to popular belief, this is not true with copyrighted material. What makes images, text, music, etc., copyrighted? It's not the All Rights Reserved warning at the bottom of the page, nor anything special about "published" versus "unpublished" material. Every piece of material you create is automatically subject to copyright law as soon as you bring it into existence.

The Berne Convention for the Protection of Literary and Artistic Works, named after Berne, Switzerland, where it was first adopted in 1886, is the international standard for copyright. This convention says, in essence, that all member countries must recognize the copyright protection of the works of citizens of other member countries as if they were citizens of their own country. In practice, this means that, as a US citizen,

you can be held accountable in the United States for violating the copyright of material written by someone in, say, France (and vice versa).

Obviously, copyright is a concern for web scrapers. If I scrape content from someone's blog and publish it on my own blog, I could very well be opening myself up to a lawsuit. Fortunately, I have several layers of protection that might make my blog-scraping project defensible, depending on how it functions.

First, copyright protection extends to creative works only. It does not cover statistics or facts. Fortunately, much of what web scrapers are after *are* statistics and facts. Although a web scraper that gathers poetry from around the web and displays that poetry on your own website might be violating copyright law, a web scraper that gathers information on the frequency of poetry postings over time is not. The poetry, in its raw form, is a creative work. The average word count of poems published on a website by month is factual data and not a creative work.

Content that is posted verbatim (as opposed to aggregated/calculated content from raw scraped data) might not be violating copyright law if that data is prices, names of company executives, or some other factual piece of information.

Even copyrighted content can be used directly, within reason, under the Digital Millennium Copyright Act. The DMCA outlines some rules for the automated handling of copyrighted material. The DMCA is long, with many specific rules governing everything from ebooks to telephones. However, two main points may be of particular relevance to web scraping:

- Under the "safe harbor" protection, if you scrape material from a source that you are led to believe contains only copyright-free material, but a user has submitted copyright material to, you are protected as long as you removed the copyrighted material when notified.
- You cannot circumvent security measures (such as password protection) in order to gather content.

In addition, the DMCA also acknowledges that fair use under the US Code applies, and that take-down notices may not be issued according to the safe harbor protection if the use of the copyrighted material falls under fair use.

In short, you should never directly publish copyrighted material without permission from the original author or copyright holder. If you are storing copyrighted material that you have free access to in your own nonpublic database for the purposes of analysis, that is fine. If you are publishing that database to your website for viewing or download, that is not fine. If you are analyzing that database and publishing statistics about word counts, a list of authors by prolificacy, or some other meta-analysis of the data, that is fine. If you are accompanying that meta-analysis with a few select quotes,

or brief samples of data to make your point, that is likely also fine, but you might want to examine the fair-use clause in the US Code to make sure.

Trespass to Chattels

Trespass to chattels is fundamentally different from what we think of as "trespassing laws" in that it applies not to real estate or land but to movable property (such as a server). It applies when your access to property is interfered with in some way that does not allow you to access or use it.

In this era of cloud computing, it's tempting not to think of web servers as real, tangible resources. However, not only do servers consist of expensive components, but they need to be stored, monitored, cooled, and supplied with vast amounts of electricity. By some estimates, 10% of global electricity usage is consumed by computers.[1] (If a survey of your own electronics doesn't convince you, consider Google's vast server farms, all of which need to be connected to large power stations.)

Although servers are expensive resources, they're interesting from a legal perspective in that webmasters generally *want* people to consume their resources (i.e., access their websites); they just don't want them to consume their resources *too much*. Checking out a website via your browser is fine; launching a full-scale DDOS against it obviously is not.

Three criteria need to be met for a web scraper to violate trespass to chattels:

Lack of consent
: Because web servers are open to everyone, they are generally "giving consent" to web scrapers as well. However, many websites' Terms of Service agreements specifically prohibit the use of scrapers. In addition, any cease-and-desist notices delivered to you obviously revoke this consent.

Actual harm
: Servers are costly. In addition to server costs, if your scrapers take a website down, or limit its ability to serve other users, this can add to the "harm" you cause.

Intentionality
: If you're writing the code, you know what it does!

You must meet all three of these criteria for trespass to chattels to apply. However, if you are violating a Terms of Service agreement, but not causing actual harm, don't think that you're immune from legal action. You might very well be violating copy-

1 Bryan Walsh, "The Surprisingly Large Energy Footprint of the Digital Economy [UPDATE]", TIME.com, August 14, 2013.

right law, the DMCA, the Computer Fraud and Abuse Act (more on that later), or one of the other myriad of laws that apply to web scrapers.

Throttling Your Bots

Back in the olden days, web servers were far more powerful than personal computers. In fact, part of the definition of *server* was *big computer*. Now, the tables have turned somewhat. My personal computer, for instance, has a 3.5 GHz processor and 8 GB of RAM. An Amazon medium instance, in contrast (as of the writing of this book), has 4 GB of RAM and about 3 GHz of processing capacity.

With a decent internet connection and a dedicated machine, even a single personal computer can place a heavy load on many websites, even crippling them or taking them down completely. Unless there's a medical emergency and the only cure is aggregating all the data from Joe Schmo's website in two seconds flat, there's really no reason to hammer a site.

A watched bot never completes. Sometimes it's better to leave crawlers running overnight than in the middle of the afternoon or evening for a few reasons:

- If you have about eight hours, even at the glacial pace of two seconds per page, you can crawl over 14,000 pages. When time is less of an issue, you're not tempted to push the speed of your crawlers.
- Assuming the target audience of the website is in your general location (adjust accordingly for remote target audiences), the website's traffic load is probably far lower during the night, meaning that your crawling will not be compounding peak traffic hour congestion.
- You save time by sleeping, instead of constantly checking your logs for new information. Think of how excited you'll be to wake up in the morning to brand-new data!

Consider the following scenarios:

- You have a web crawler that traverses Joe Schmo's website, aggregating some or all of its data.
- You have a web crawler that traverses hundreds of small websites, aggregating some or all of their data.
- You have a web crawler that traverses a very large site, such as Wikipedia.

In the first scenario, it's best to leave the bot running slowly, and during the night.

In the second scenario, it's best to crawl each website in a round-robin fashion, rather than crawling them slowly, one at a time. Depending on how many websites you're crawling, this means that you can collect data as fast as your internet connection and machine can manage, yet the load is reasonable for each individual remote server.

You can accomplish this programmatically, either using multiple threads (where each individual thread crawls a single site and pauses its own execution), or using Python lists to keep track of sites.

In the third scenario, the load your internet connection and home machine can place on a site like Wikipedia is unlikely to be noticed or cared much about. However, if you're using a distributed network of machines, this is obviously a different matter. Use caution, and ask a company representative whenever possible.

The Computer Fraud and Abuse Act

In the early 1980s, computers started moving out of academia and into the business world. For the first time, viruses and worms were seen as more than an inconvenience (or even a fun hobby) and as a serious criminal matter that could cause monetary damages. In response, the Computer Fraud and Abuse Act was created in 1986.

Although you might think that the act applies to only a stereotypical version of a malicious hacker unleashing viruses, the act has strong implications for web scrapers as well. Imagine a scraper that scans the web looking for login forms with easy-to-guess passwords, or collects government secrets accidentally left in a hidden but public location. All of these activities are illegal (and rightly so) under the CFAA.

The act defines seven main criminal offenses, which can be summarized as follows:

- The knowing unauthorized access of computers owned by the US government and obtaining information from those computers.
- The knowing unauthorized access of a computer, obtaining financial information.
- The knowing unauthorized access of a computer owned by the US government, affecting the use of that computer by the government.
- Knowingly accessing any protected computer with the attempt to defraud.
- Knowingly accessing a computer without authorization and causing damage to that computer.
- Shares or traffics passwords or authorization information for computers used by the US government or computers that affect interstate or foreign commerce.
- Attempts to extort money or "anything of value" by causing damage, or threatening to cause damage, to any protected computer.

In short: stay away from protected computers, do not access computers (including web servers) that you are not given access to, and especially, stay away from government or financial computers.

robots.txt and Terms of Service

A website's terms of service and *robots.txt* files are in interesting territory, legally speaking. If a website is publicly accessible, the webmaster's right to declare what software can and cannot access it is debatable. Saying "it is fine if you use your browser to view this site, but not if you use a program you wrote to view it" is tricky.

Most sites have a link to their Terms of Service in the footer on every page. The TOS contains more than just the rules for web crawlers and automated access; it often has information about what kind of information the website collects, what it does with it, and usually a legal disclaimer that the services provided by the website come without any express or implied warranty.

If you are interested in search engine optimization (SEO) or search engine technology, you've probably heard of the *robots.txt* file. If you go to just about any large website and look for its *robots.txt* file, you will find it in the root web folder: *http://website.com/robots.txt*.

The syntax for *robots.txt* files was developed in 1994 during the initial boom of web search engine technology. It was about this time that search engines scouring the entire internet, such as AltaVista and DogPile, started competing in earnest with simple lists of sites organized by subject, such as the one curated by Yahoo! This growth of search across the internet meant an explosion in not only the number of web crawlers, but in the availability of information collected by those web crawlers to the average citizen.

While we might take this sort of availability for granted today, some webmasters were shocked when information they published deep in the file structure of their website became available on the front page of search results in major search engines. In response, the syntax for *robots.txt* files, called the Robots Exclusion Standard, was developed.

Unlike the TOS, which often talks about web crawlers in broad terms and in very human language, *robots.txt* can be parsed and used by automated programs extremely easily. Although it might seem like the perfect system to solve the problem of unwanted bots once and for all, keep in mind the following:

- There is no official governing body for the syntax of *robots.txt*. It is a commonly used and generally well-followed convention, but there is nothing to stop anyone from creating their own version of a *robots.txt* file (apart from the fact that no bot will recognize or obey it until it gets popular). That being said, it is a widely accepted convention, mostly because it is relatively straightforward, and there is no incentive for companies to invent their own standard or try to improve on it.
- There is no way to enforce a *robots.txt* file. It is merely a sign that says "Please don't go to these parts of the site." Many web scraping libraries are available that

obey *robots.txt* (although this is often merely a default setting that can be overridden). Beyond that, there are often more barriers to following a *robots.txt* file (after all, you need to scrape, parse, and apply the contents of the page to your code logic) than there are to just going ahead and scraping whatever page you want to.

The Robot Exclusion Standard syntax is fairly straightforward. As in Python (and many other languages), comments begin with a `#` symbol, end with a newline, and can be used anywhere in the file.

The first line of the file, apart from any comments, is started with `User-agent:`, which specifies the user that the following rules apply to. This is followed by a set of rules, either `Allow:` or `Disallow:`, depending on whether the bot is allowed on that section of the site. An asterisk (*) indicates a wildcard and can be used to describe either a `User-agent` or a URL.

If a rule follows a rule that it seems to contradict, the last rule takes precedence. For example:

```
#Welcome to my robots.txt file!
User-agent: *
Disallow: *

User-agent: Googlebot
Allow: *
Disallow: /private
```

In this case, all bots are disallowed from anywhere on the site, except for the Googlebot, which is allowed anywhere except for the */private* directory.

Twitter's *robots.txt* file has explicit instructions for the bots of Google, Yahoo!, Yandex (a popular Russian search engine), Microsoft, and other bots or search engines not covered by any of the preceding categories. The Google section (which looks identical to the permissions allowed to all other categories of bots) looks like this:

```
#Google Search Engine Robot
User-agent: Googlebot
Allow: /?_escaped_fragment_

Allow: /?lang=
Allow: /hashtag/*?src=
Allow: /search?q=%23
Disallow: /search/realtime
Disallow: /search/users
Disallow: /search/*/grid

Disallow: /*?
Disallow: /*/followers
Disallow: /*/following
```

Notice that Twitter restricts access to the portions of its site that it has an API in place for. Because Twitter has a well-regulated API (and one that it can make money off of by licensing), it is in the company's best interest to disallow any "home-brewed APIs" that gather information by independently crawling its site.

Although a file telling your crawler where it can't go might seem restrictive at first, it can be a blessing in disguise for web crawler development. If you find a *robots.txt* file that disallows crawling in a particular section of the site, the webmaster is saying, essentially, that they are fine with crawlers in all other sections of the site (after all, if they weren't fine with it, they would have restricted access when they were writing *robots.txt* in the first place).

For example, the section of Wikipedia's *robots.txt* file that applies to general web scrapers (as opposed to search engines) is wonderfully permissive. It even goes as far as containing human-readable text to welcome bots (that's us!) and blocks access to only a few pages, such as the login page, search page, and "random article" page:

```
#
# Friendly, low-speed bots are welcome viewing article pages, but not
# dynamically generated pages please.
#
# Inktomi's "Slurp" can read a minimum delay between hits; if your bot supports
# such a thing using the 'Crawl-delay' or another instruction, please let us
# know.
#
# There is a special exception for API mobileview to allow dynamic mobile web &
# app views to load section content.
# These views aren't HTTP-cached but use parser cache aggressively and don't
# expose special: pages etc.
#
User-agent: *
Allow: /w/api.php?action=mobileview&
Disallow: /w/
Disallow: /trap/
Disallow: /wiki/Especial:Search
Disallow: /wiki/Especial%3ASearch
Disallow: /wiki/Special:Collection
Disallow: /wiki/Spezial:Sammlung
Disallow: /wiki/Special:Random
Disallow: /wiki/Special%3ARandom
Disallow: /wiki/Special:Search
Disallow: /wiki/Special%3ASearch
Disallow: /wiki/Spesial:Search
Disallow: /wiki/Spesial%3ASearch
Disallow: /wiki/Spezial:Search
Disallow: /wiki/Spezial%3ASearch
Disallow: /wiki/Specjalna:Search
Disallow: /wiki/Specjalna%3ASearch
Disallow: /wiki/Speciaal:Search
Disallow: /wiki/Speciaal%3ASearch
```

```
Disallow: /wiki/Speciaal:Random
Disallow: /wiki/Speciaal%3ARandom
Disallow: /wiki/Speciel:Search
Disallow: /wiki/Speciel%3ASearch
Disallow: /wiki/Speciale:Search
Disallow: /wiki/Speciale%3ASearch
Disallow: /wiki/Istimewa:Search
Disallow: /wiki/Istimewa%3ASearch
Disallow: /wiki/Toiminnot:Search
Disallow: /wiki/Toiminnot%3ASearch
```

Whether you choose to write web crawlers that obey *robots.txt* is up to you, but I highly recommend it, particularly if you have crawlers that indiscriminately crawl the web.

Three Web Scrapers

Because web scraping is such a limitless field, there are a staggering number of ways to land yourself in legal hot water. This section presents three cases that touched on some form of law that generally applies to web scrapers, and how it was used in that case.

eBay versus Bidder's Edge and Trespass to Chattels

In 1997, the Beanie Baby market was booming, the tech sector was bubbling, and online auction houses were the hot new thing on the internet. A company called Bidder's Edge formed and created a new kind of meta-auction site. Rather than force you to go from auction site to auction site, comparing prices, it would aggregate data from all current auctions for a specific product (say, a hot new Furby doll or a copy of *Spice World*) and point you to the site that had the lowest price.

Bidder's Edge accomplished this with an army of web scrapers, constantly making requests to the web servers of the various auction sites in order to get price and product information. Of all the auction sites, eBay was the largest, and Bidder's Edge hit eBay's servers about 100,000 times a day. Even by today's standards, this is a lot of traffic. According to eBay, this was 1.53% of its total internet traffic at the time, and it certainly wasn't happy about it.

eBay sent Bidder's Edge a cease-and-desist letter, coupled with an offer to license its data. However, negotiations for this licensing failed, and Bidder's Edge continued to crawl eBay's site.

eBay tried blocking IP addresses used by Bidder's Edge, blocking 169 IP addresses—although Bidder's Edge was able to get around this by using proxy servers (servers that forward requests on behalf of another machine, but using the proxy server's own IP address). As I'm sure you can imagine, this was a frustrating and unsustainable solution for both parties—Bidder's Edge was constantly trying to find new proxy

servers and buy new IP addresses while old ones were blocked, and eBay was forced to maintain large firewall lists (and adding computationally expensive IP address-comparing overhead to each packet check).

Finally, in December of 1999, eBay sued Bidder's Edge under trespass to chattels.

Because eBay's servers were real, tangible resources that it owned, and it didn't appreciate Bidder's Edge's abnormal use of them, trespass to chattels seemed like the ideal law to use. In fact, in modern times, trespass to chattels goes hand in hand with web-scraping lawsuits, and is most often thought of as an IT law.

The courts ruled that in order for eBay to win its case using trespass to chattels, eBay had to show two things:

- Bidder's Edge did not have permission to use eBay's resources.
- eBay suffered financial loss as a result of Bidder's Edge's actions.

Given the record of eBay's cease-and-desist letters, coupled with IT records showing server usage and actual costs associated with the servers, this was relatively easy for eBay to do. Of course, no large court battles end easily: countersuits were filed, many lawyers were paid, and the matter was eventually settled out of court for an undisclosed sum in March 2001.

So does this mean that any unauthorized use of another person's server is automatically a violation of trespass to chattels? Not necessarily. Bidder's Edge was an extreme case; it was using so many of eBay's resources that the company had to buy additional servers, pay more for electricity, and perhaps hire additional personnel (although 1.53% might not seem like a lot, in large companies, it can add up to a significant amount).

In 2003, the California Supreme Court ruled on another case, Intel Corp versus Hamidi, in which a former Intel employee (Hamidi) sent emails Intel didn't like, across Intel's servers, to Intel employees. The court said:

> Intel's claim fails not because e-mail transmitted through the internet enjoys unique immunity, but because the trespass to chattels tort—unlike the causes of action just mentioned—may not, in California, be proved without evidence of an injury to the plaintiff's personal property or legal interest therein.

Essentially, Intel had failed to prove that the costs of transmitting the six emails sent by Hamidi to all employees (each one, interestingly enough, with an option to be removed from Hamidi's mailing list—at least he was polite!) contributed to any financial injury for them. It did not deprive Intel of any property or use of their property.

United States v. Auernheimer and The Computer Fraud and Abuse Act

If information is readily accessible on the internet to a human using a web browser, it's unlikely that accessing the same exact information in an automated fashion would land you in hot water with the Feds. However, as easy as it can be for a sufficiently curious person to find a small security leak, that small security leak can quickly become a much larger and much more dangerous one when automated scrapers enter the picture.

In 2010, Andrew Auernheimer and Daniel Spitler noticed a nice feature of iPads: when you visited AT&T's website on them, AT&T would redirect you to a URL containing your iPad's unique ID number:

```
https://dcp2.att.com/OEPClient/openPage?ICCID=<idNumber>&IMEI=
```

This page would contain a login form, with the email address of the user whose ID number was in the URL. This allowed users to gain access to their accounts simply by entering their password.

Although there were a large number of potential iPad ID numbers, it was possible, given enough web scrapers, to iterate through the possible numbers, gathering email addresses along the way. By providing users with this convenient login feature, AT&T, in essence, made its customer email addresses public to the web.

Auernheimer and Spitler created a scraper that collected 114,000 of these email addresses, among them the private email addresses of celebrities, CEOs, and government officials. Auernheimer (but not Spitler) then sent the list, and information about how it was obtained, to Gawker Media, which published the story (but not the list) under the headline: "Apple's Worst Security Breach: 114,000 iPad Owners Exposed."

In June 2011, Auernheimer's home was raided by the FBI in connection with the email address collection, although they ended up arresting him on drug charges. In November 2012, he was found guilty of identity fraud and conspiracy to access a computer without authorization, and later sentenced to 41 months in federal prison and ordered to pay $73,000 in restitution.

His case caught the attention of civil rights lawyer Orin Kerr, who joined his legal team and appealed the case to the Third Circuit Court of Appeals. On April 11, 2014 (these legal processes can take quite a while), the Third Circuit agreed with the appeal, saying:

> Auernheimer's conviction on Count 1 must be overturned because visiting a publicly available website is not unauthorized access under the Computer Fraud and Abuse Act, 18 U.S.C. § 1030(a)(2)(C). AT&T chose not to employ passwords or any other protective measures to control access to the e-mail addresses of its customers. It is irrelevant that AT&T subjectively wished that outsiders would not stumble across the data or that Auernheimer hyperbolically characterized the access as a "theft." The company config-

> ured its servers to make the information available to everyone and thereby authorized the general public to view the information. Accessing the e-mail addresses through AT&T's public website was authorized under the CFAA and therefore was not a crime.

Thus, sanity prevailed in the legal system, Auernheimer was released from prison that same day, and everyone lived happily ever after.

Although it was ultimately decided that Auernheimer did not violate the Computer Fraud and Abuse Act, he had his house raided by the FBI, spent many thousands of dollars in legal fees, and spent three years in and out of courtrooms and prisons. As web scrapers, what lessons can we take away from this to avoid similar situations?

Scraping any sort of sensitive information, whether it's personal data (in this case, email addresses), trade secrets, or government secrets, is probably not something you want to do without having a lawyer on speed dial. Even if it's publicly available, think: "Would the average computer user be able to easily access this information if they wanted to see it?" or "Is this something the company wants users to see?"

I have on many occasions called companies to report security vulnerabilities in their websites and web applications. This line works wonders: "Hi, I'm a security professional who discovered a potential security vulnerability on your website. Could you direct me to someone so that I can report it and get the issue resolved?" In addition to the immediate satisfaction of recognition for your (white hat) hacking genius, you might be able to get free subscriptions, cash rewards, and other goodies out of it!

In addition, Auernheimer's release of the information to Gawker Media (before notifying AT&T) and his showboating around the exploit of the vulnerability also made him an especially attractive target for AT&T's lawyers.

If you find security vulnerabilities in a site, the best thing to do is to alert the owners of the site, not the media. You might be tempted to write up a blog post and announce it to the world, especially if a fix to the problem is not put in place immediately. However, you need to remember that it is the company's responsibility, not yours. The best thing you can do is take your web scrapers (and, if applicable, your business) away from the site!

Field v. Google: Copyright and robots.txt

Blake Field, an attorney, filed a lawsuit against Google on the basis that its site-caching feature violated copyright law by displaying a copy of his book after he had removed it from his website. Copyright law allows the creator of an original creative work to have control over the distribution of that work. Field's argument was that Google's caching (after he had removed it from his website) removed his ability to control its distribution.

The Google Web Cache

When Google web scrapers (also known as *Google bots*) crawl websites, they make a copy of the site and host it on the internet. Anyone can access this cache, using the URL format:

```
http://webcache.googleusercontent.com/search?q=cache:http
://pythonscraping.com/
```

If a website you are searching for, or scraping, is unavailable, you might want to check there to see if a usable copy exists!

Knowing about Google's caching feature and not taking action did not help Field's case. After all, he could have prevented Google's bots from caching his website simply by adding the *robots.txt* file, with simple directives about which pages should and should not be scraped.

More important, the court found that the DMCA Safe Harbor provision allowed Google to legally cache and display sites such as Field's: "[a] service provider shall not be liable for monetary relief... for infringement of copyright by reason of the intermediate and temporary storage of material on a system or network controlled or operated by or for the service provider."

Moving Forward

The web is constantly changing. The technologies that bring us images, video, text, and other data files are constantly being updated and reinvented. To keep pace, the collection of technologies used to scrape data from the internet must also change.

Who knows? Future versions of this text may omit JavaScript entirely as an obsolete and rarely used technology and instead focus on HTML8 hologram parsing. However, what won't change is the mindset and general approach needed to successfully scrape any website (or whatever we use for "websites" in the future).

When encountering any web scraping project, you should always ask yourself:

- What is the question I want answered, or the problem I want solved?
- What data will help me achieve this, and where is it?
- How is the website displaying this data? Can I identify exactly which part of the website's code contains this information?
- How can I isolate the data and retrieve it?
- What processing or analysis needs to be done to make it more useful?
- How can I make this process better, faster, and more robust?

In addition, you need to understand not just how to use the tools presented in this book in isolation, but how they can work together to solve a larger problem. Sometimes the data is easily available and well formatted, allowing a simple scraper to do the trick. Other times you have to put some thought into it.

In Chapter 11, for example, you combined the Selenium library to identify Ajax-loaded images on Amazon and Tesseract to use OCR to read them. In the Six Degrees of Wikipedia problem, you used regular expressions to write a crawler that stored link information in a database, and then used a graph-solving algorithm in order to answer the question, "What is the shortest path of links between Kevin Bacon and Eric Idle?"

There is rarely an unsolvable problem when it comes to automated data collection on the internet. Just remember: the internet is one giant API with a somewhat poor user interface.

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About the Author

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Colophon

The animal on the cover of *Web Scraping with Python* is a ground pangolin *(Smutsia temminckii)*. The pangolin is a solitary, nocturnal mammal and closely related to armadillos, sloths, and anteaters. They can be found in southern and eastern Africa. There are three other species of pangolins in Africa and all are considered to be critically endangered.

Full-grown ground pangolins can average 12–39 inches in length and weigh from a mere 3.5–73 pounds. They resemble armadillos, covered in protective scales that are either dark, light brown, or olive in color. Immature pangolin scales are more pink. When pangolins are threatened, their scales on the tails can act more like an offensive weapon, as they are able to cut and wound attackers. Pangolins also have a defense strategy similar to skunks, in which they secrete a foul-smelling acid from glands located close to the anus. This serves as a warning to potential attackers, but also helps the pangolin mark territory. The underside of the pangolin is not covered in scales, but instead with little bits of fur.

Like those of their anteater relatives, pangolin diets consist of ants and termites. Their incredibly long tongues allow them to scavenge logs and anthills for their meals. The tongue is longer than their body and retracts into their chest cavity while at rest.

Though they are solitary animals, once matured, the ground pangolin lives in large burrows that run deep underground. In many cases, the burrows once belonged to aardvarks and warthogs, and the pangolin has simply taken over the abandoned residence. With the three, long, curved claws found on their forefeet, however, pangolins don't have a problem digging their own burrows if necessary.

Many of the animals on O'Reilly covers are endangered; all of them are important to the world. To learn more about how you can help, go to *animals.oreilly.com*.

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